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Hemisphere/Wing Grid Generation Codes

Prepared by Hiroaki Nishikawa for
Solver Technology for Turbulent flows (STT)
04-08-2017.

Available codes

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Hemisphere-cylinder grid generation code

`hcf_hc_v7p5.f90`

3D-wing grid generation code

`hcf_wing_v3p3.f90`

Topologically equivalent to HC grid.

Regular coarsening code

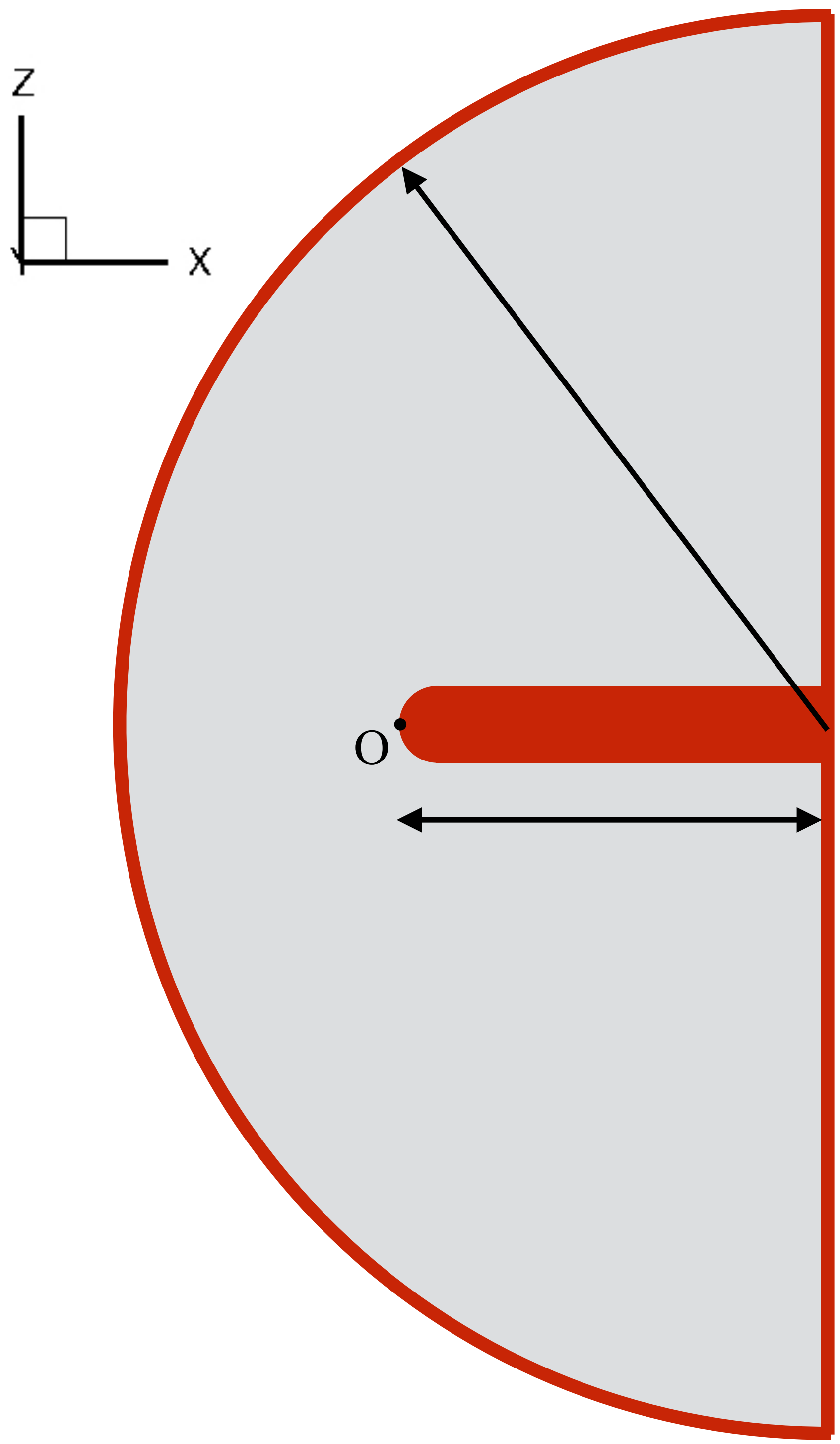
`hcf_coarsening_v2p1.f90`

This program regularly coarsens HC or 3D-wing grids.

Hemisphere Cylinder

`hcf_hc_v7p5.f90`

Geometry



Hemisphere outer boundary:

Hemisphere-cylinder:

Apex at the origin

Radius of the hemisphere = 0.5

Tetra

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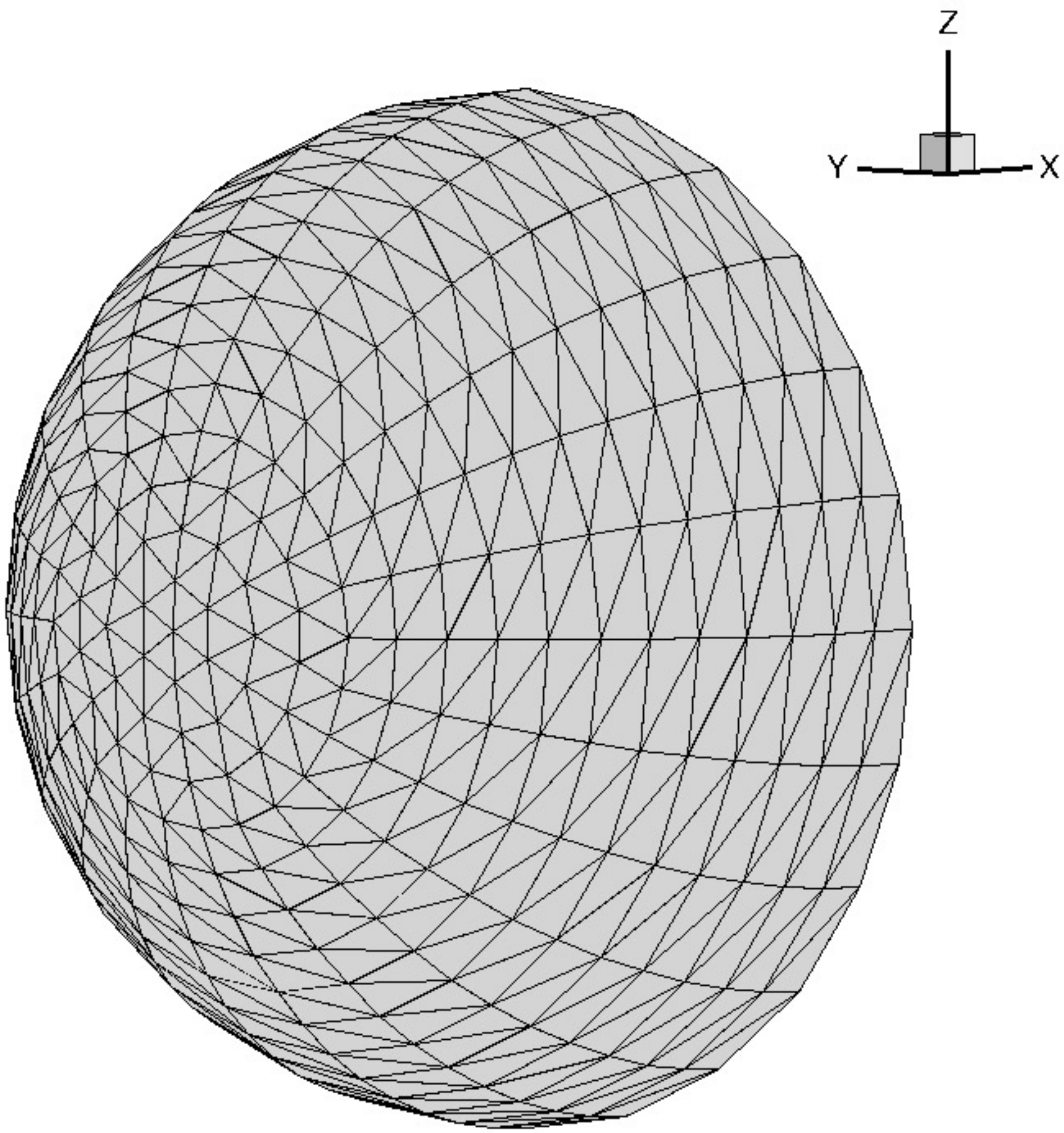
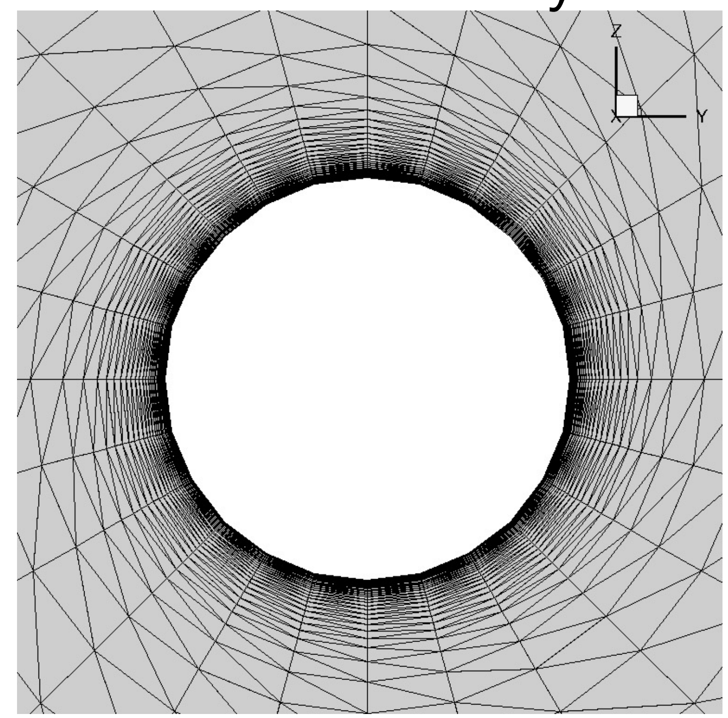
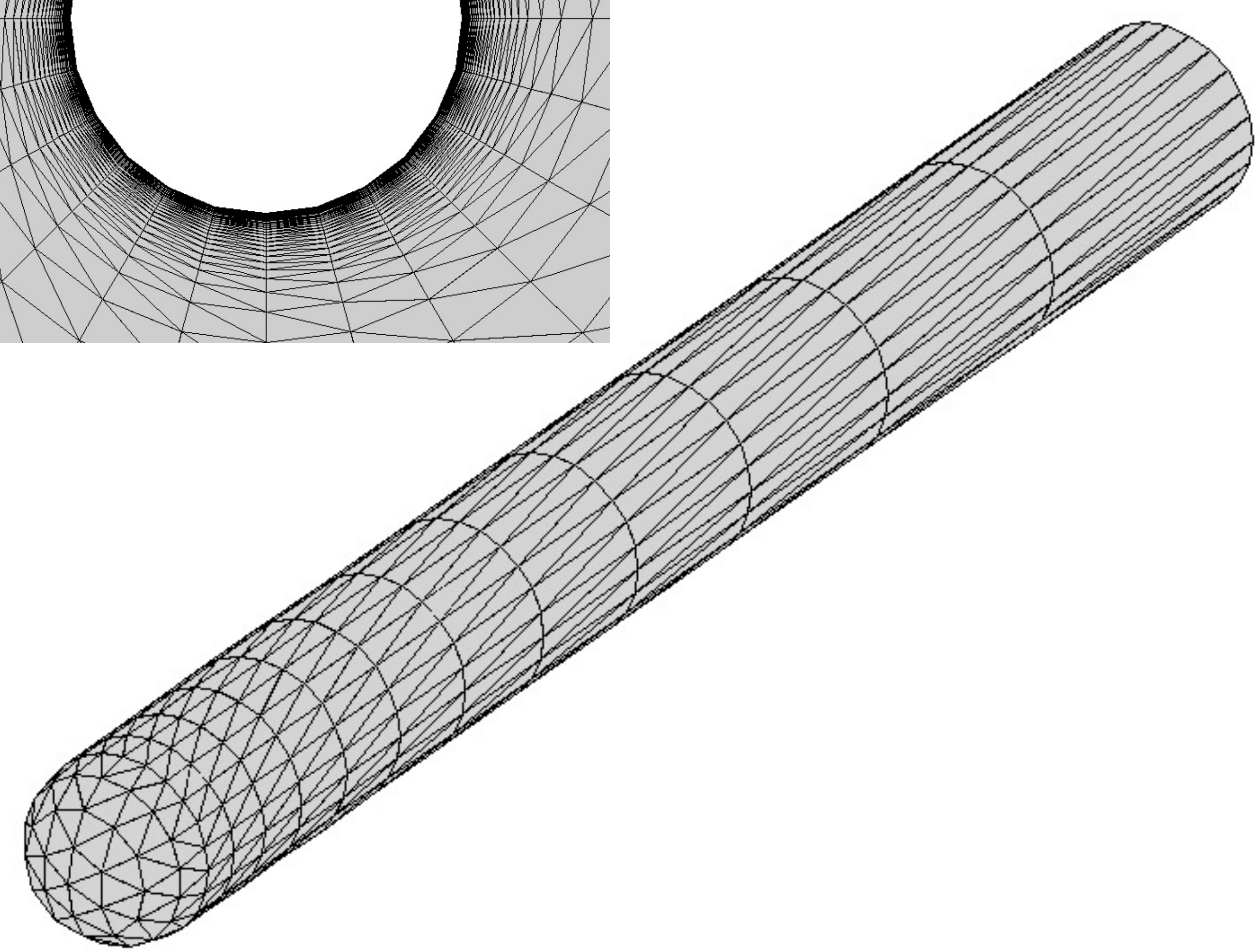
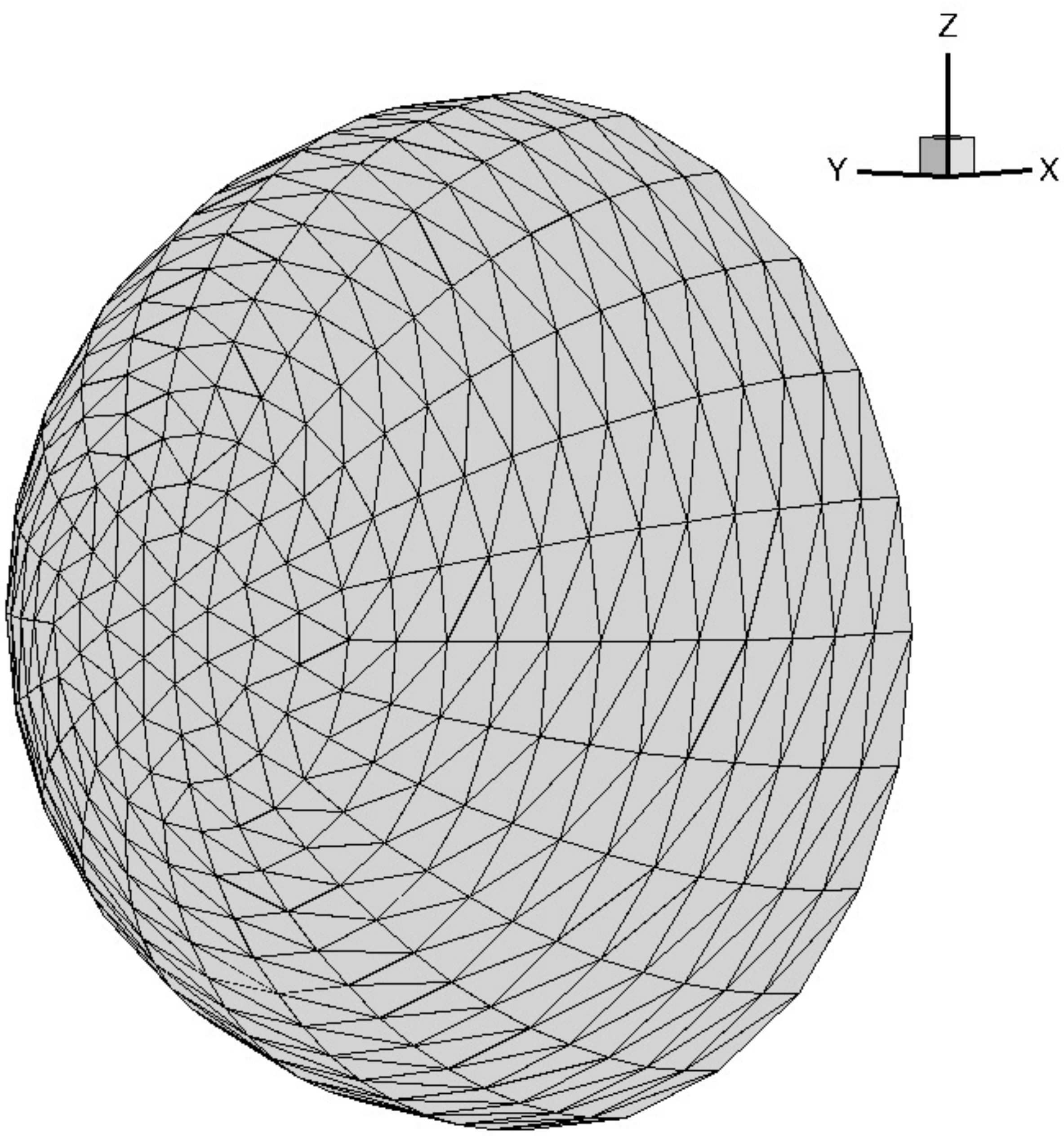


Outflow boundary

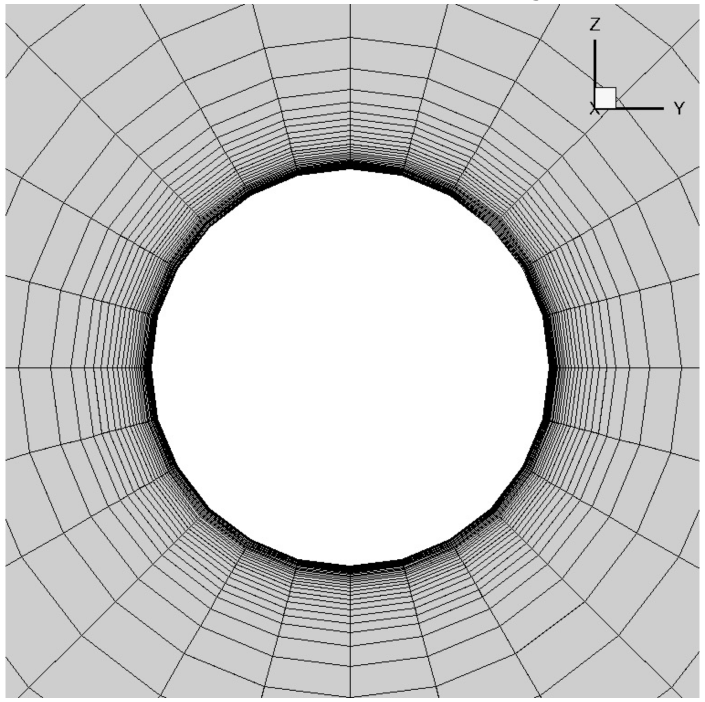


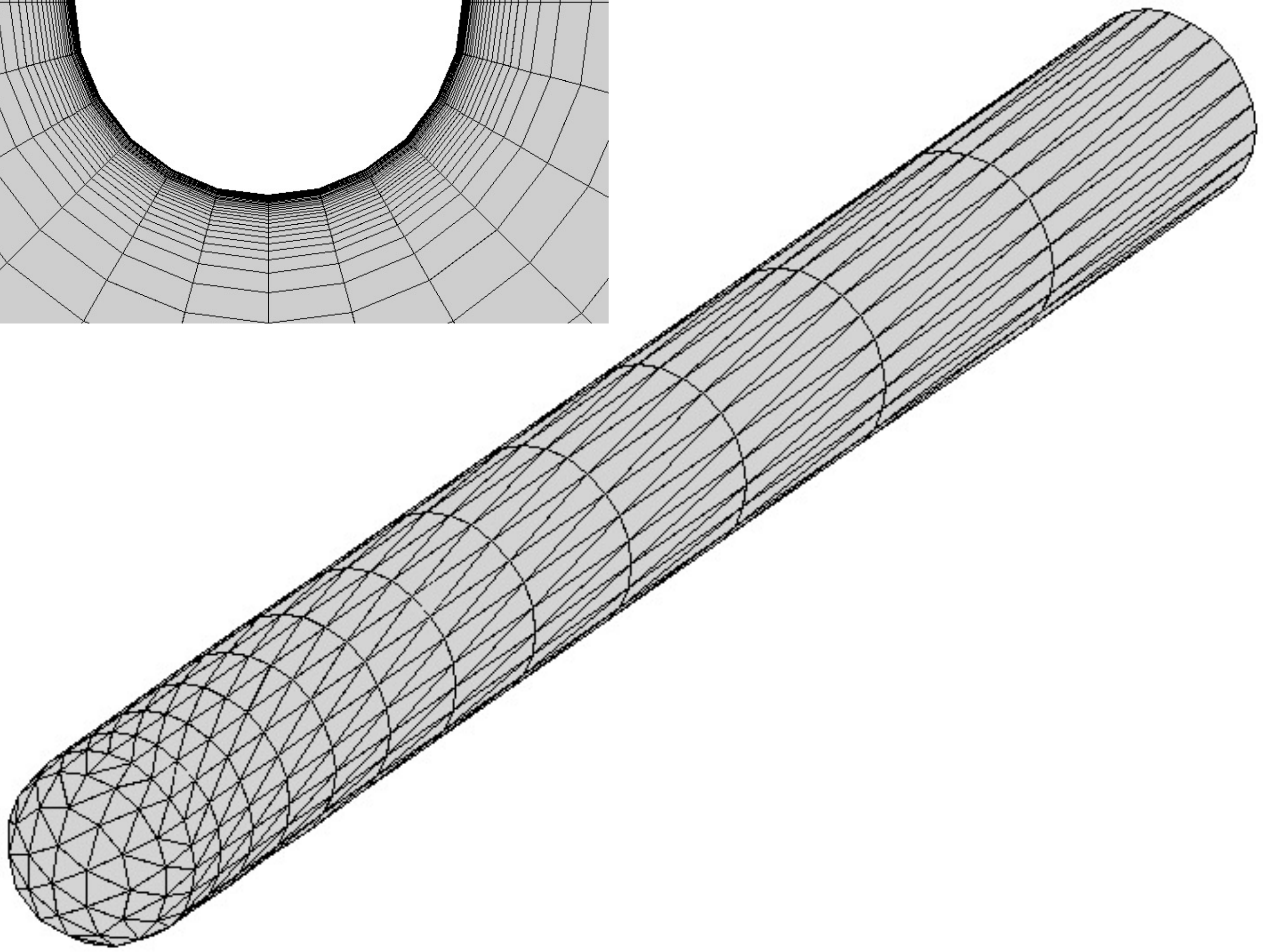


Prism

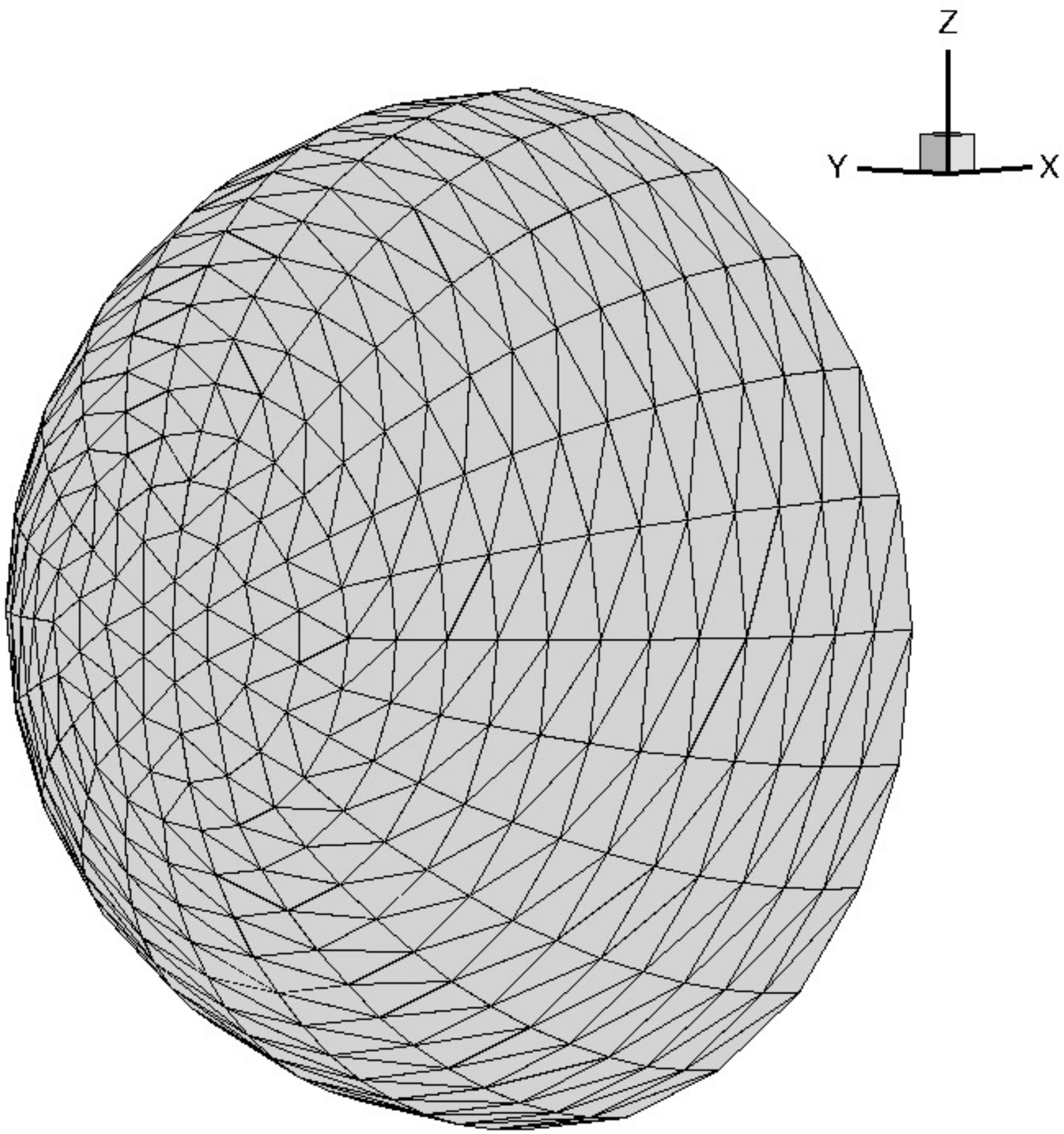


Outflow boundary

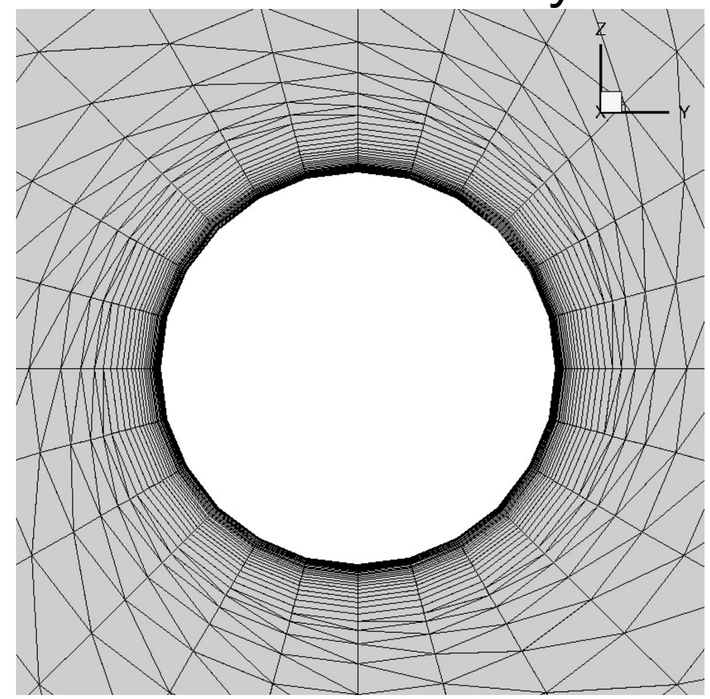


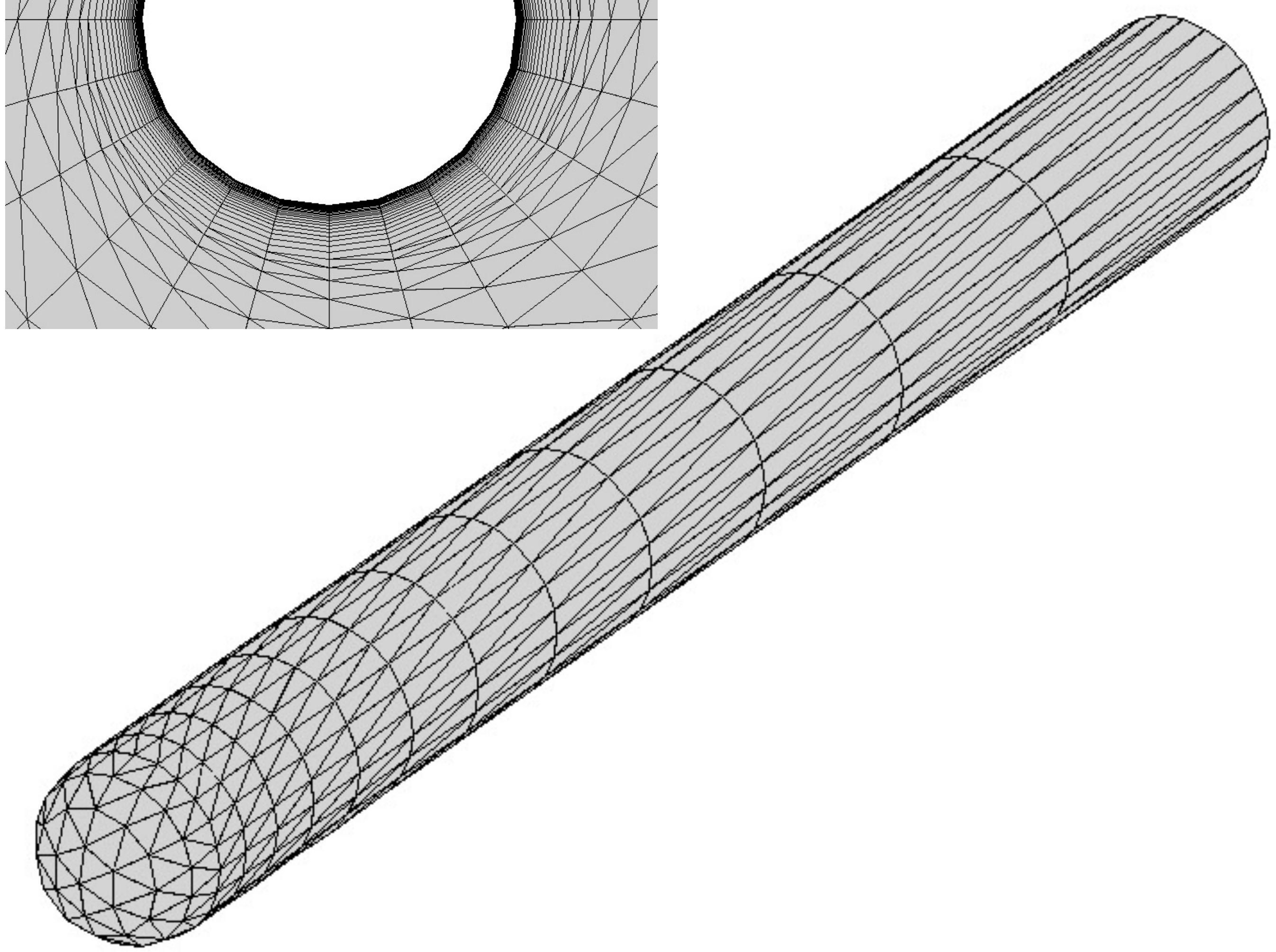


Prism-Tetra



Outflow boundary





Prism-Hex

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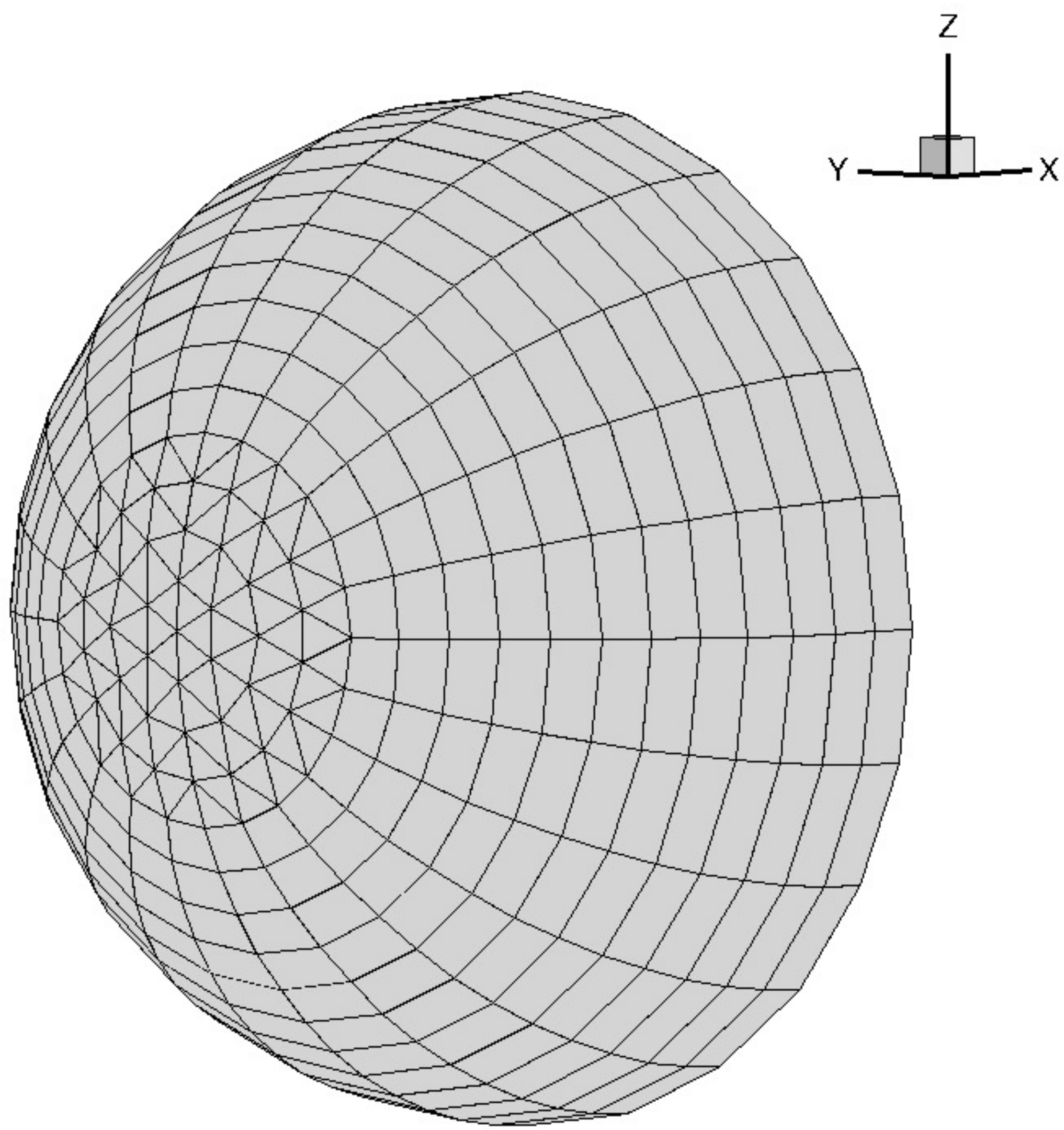
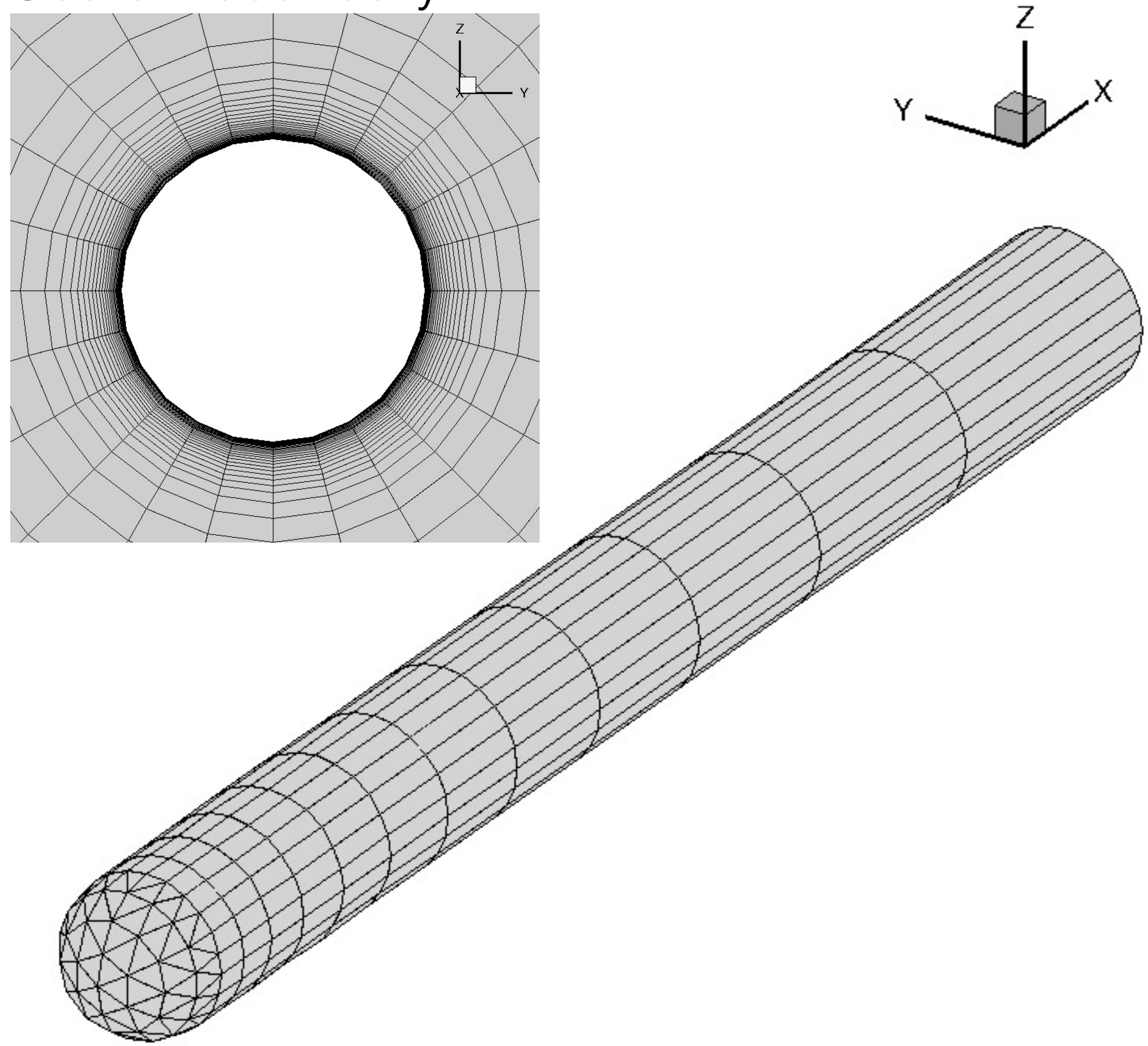
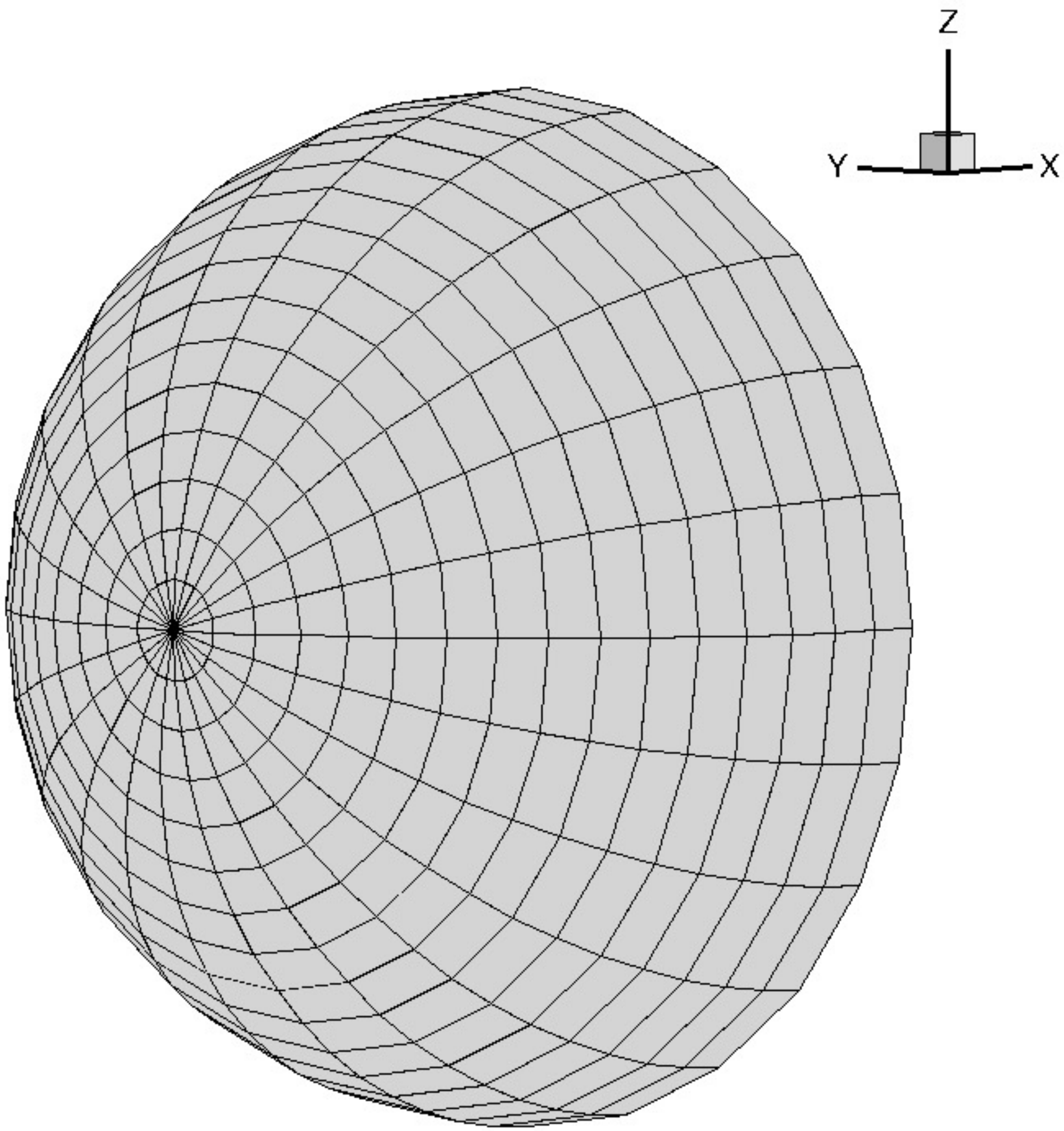


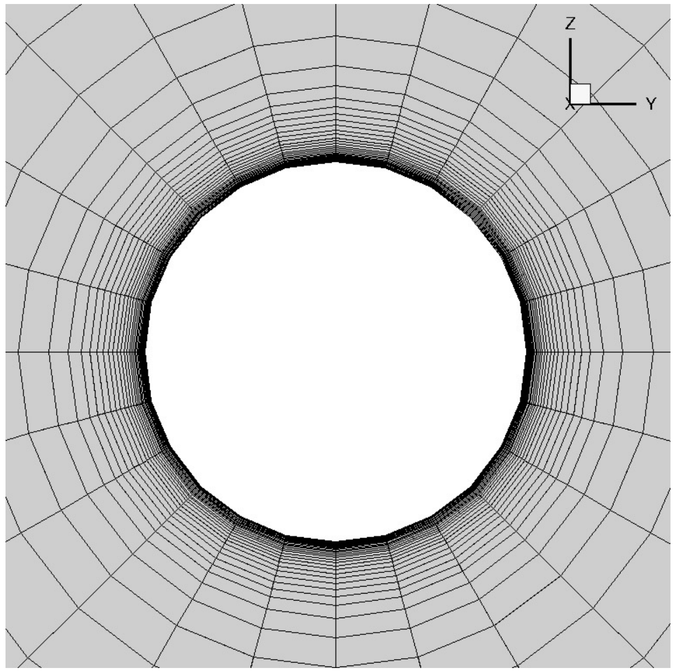
Outflow boundary

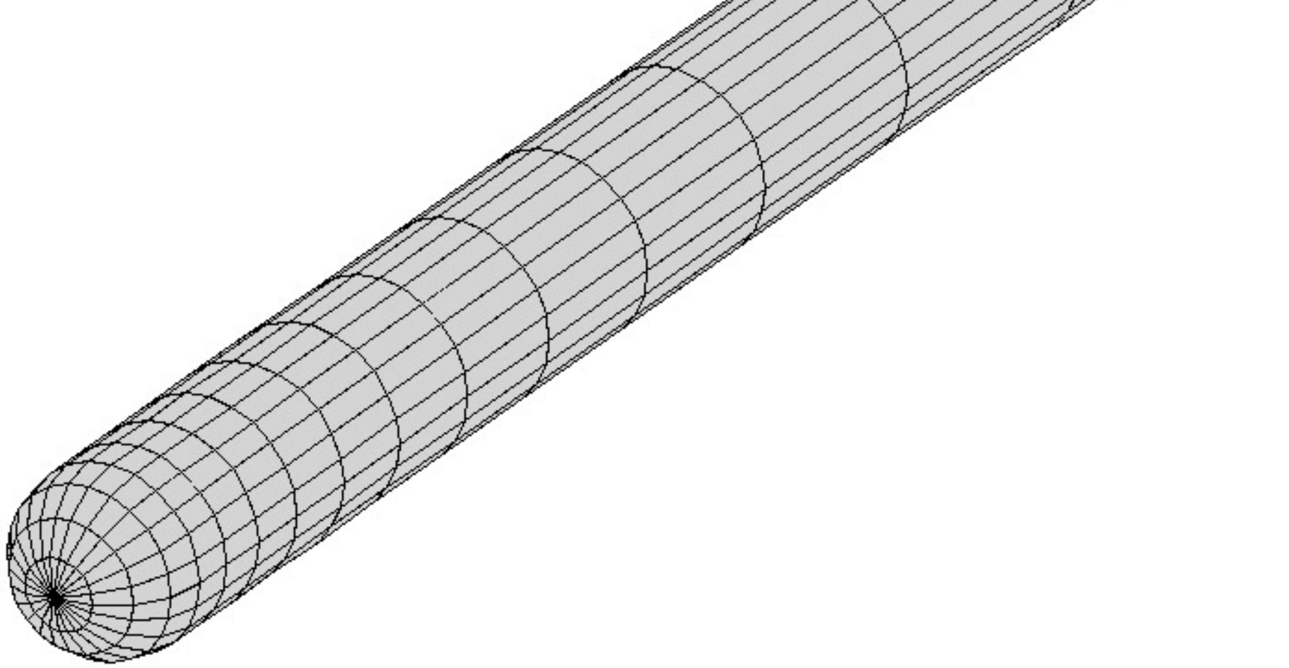


Structured (Hex+prism)

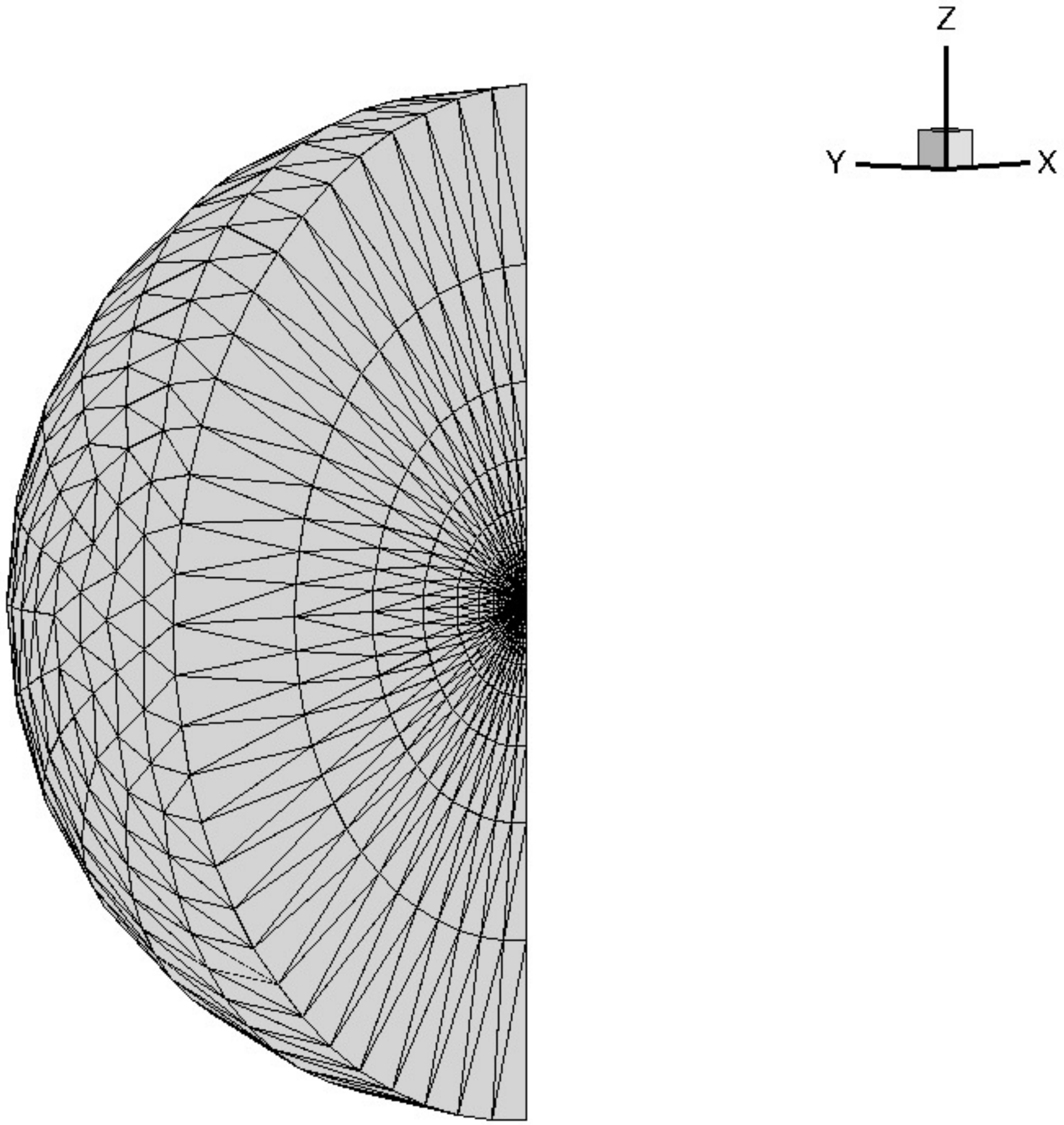


Outflow boundary

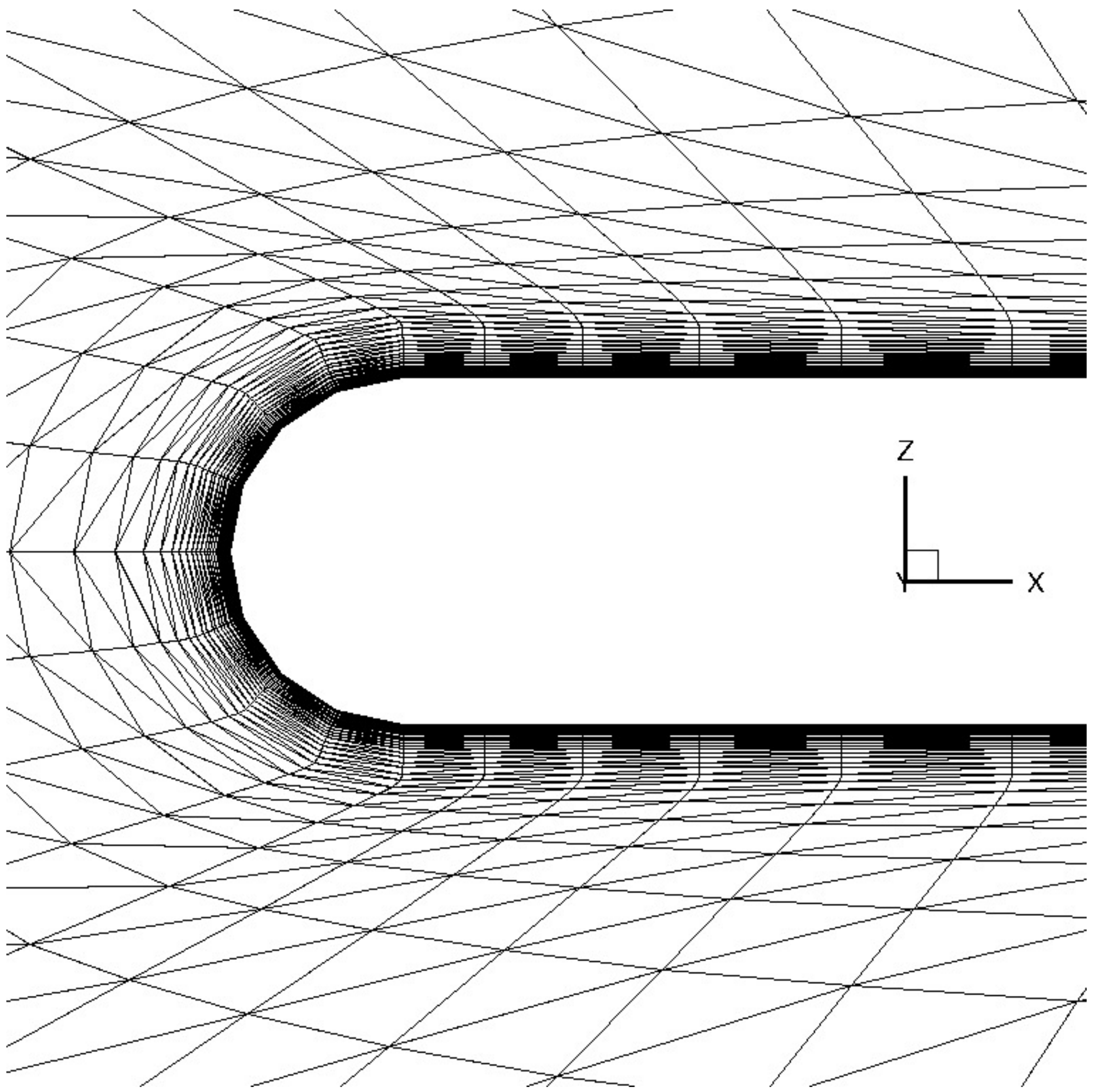




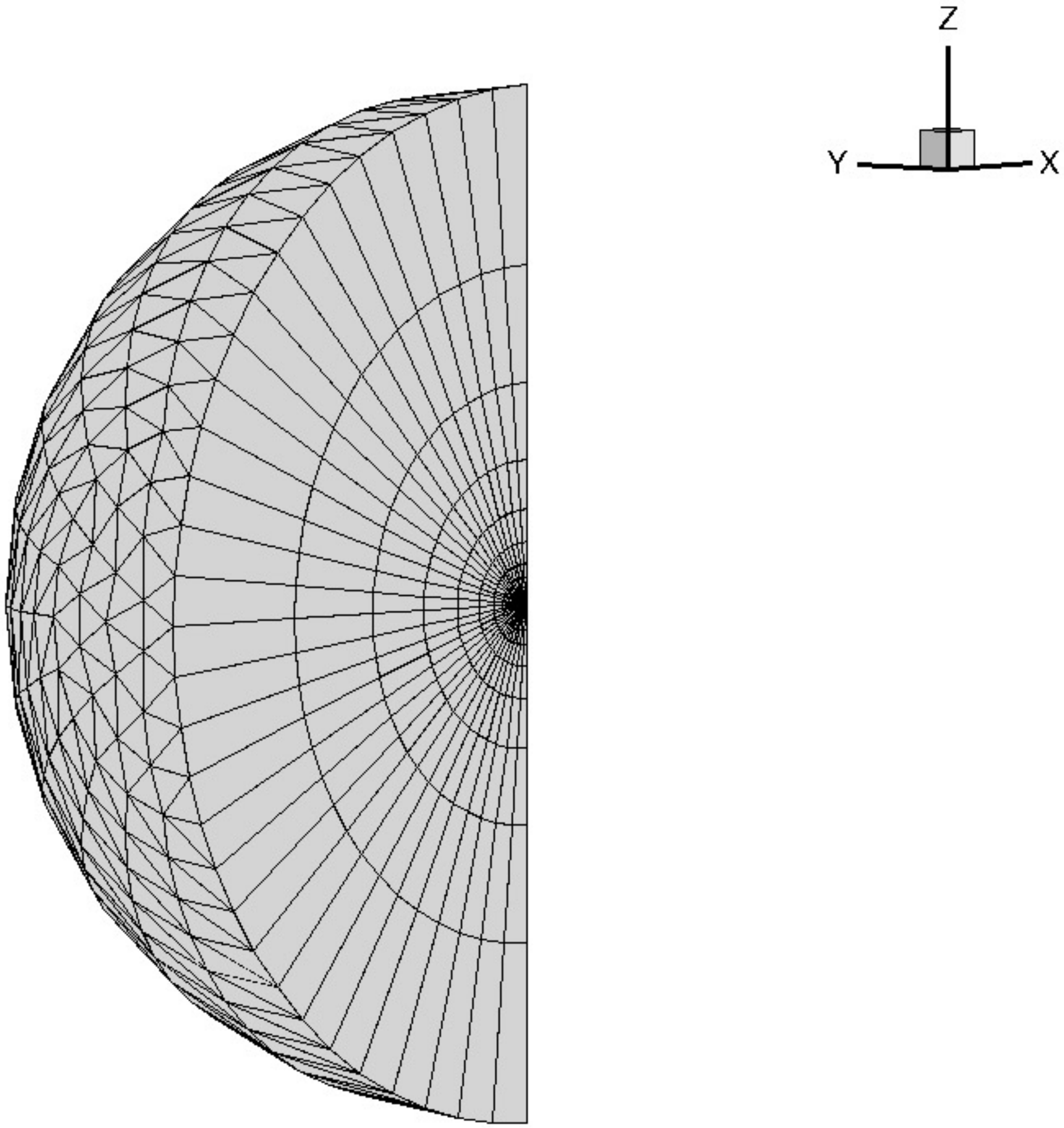
Half: Tetra



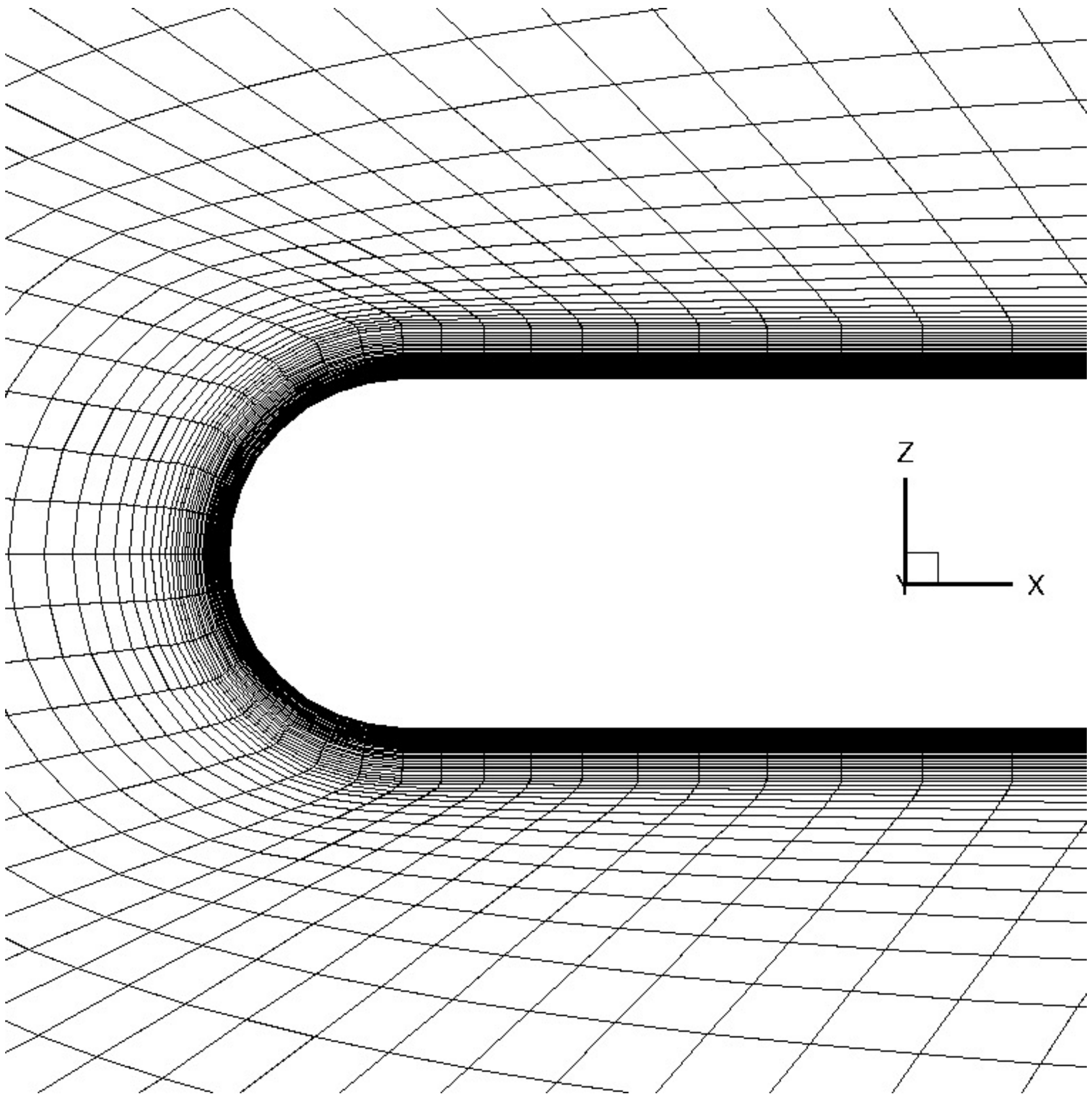
Symmetry plane



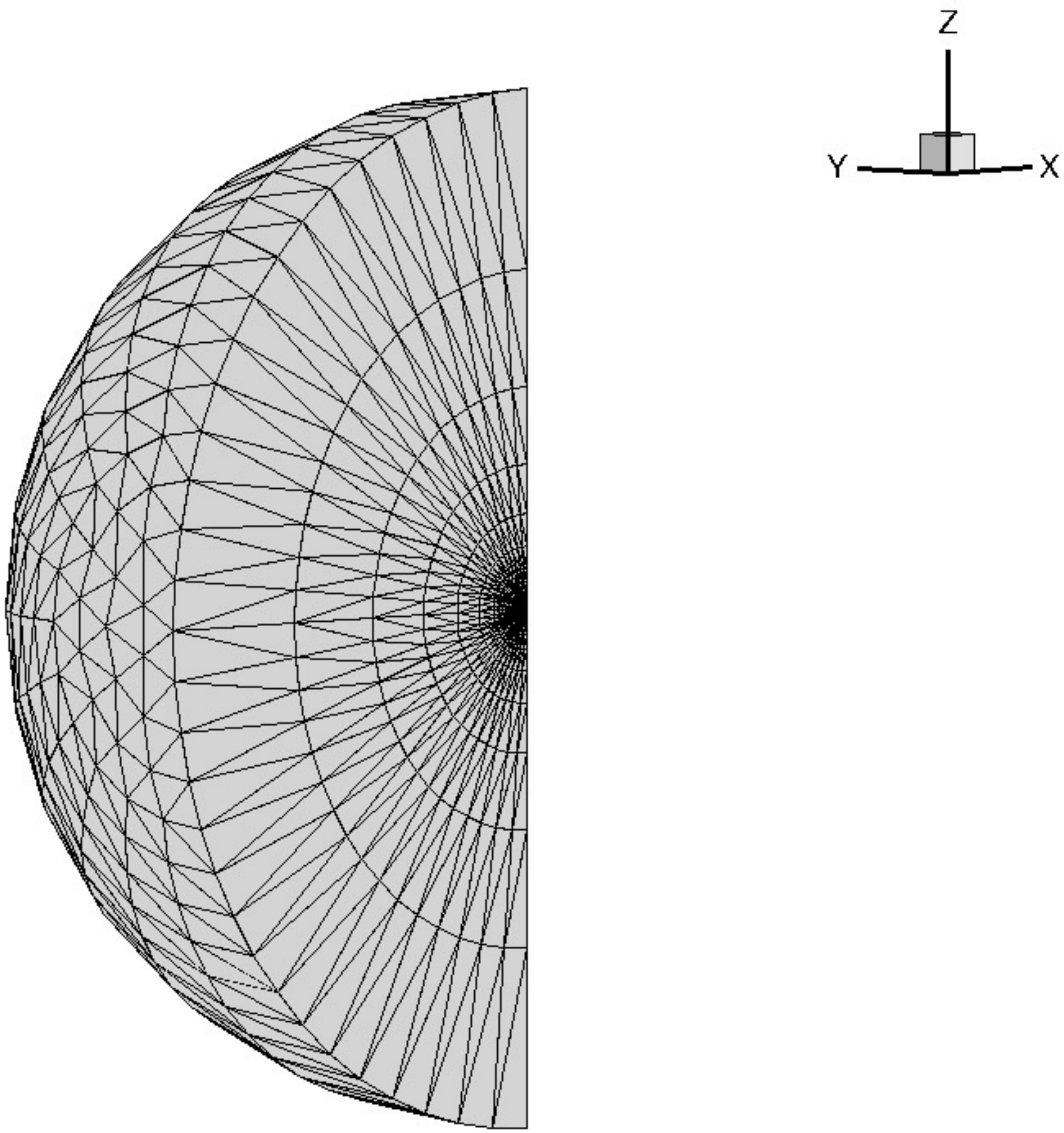
Half: Prism



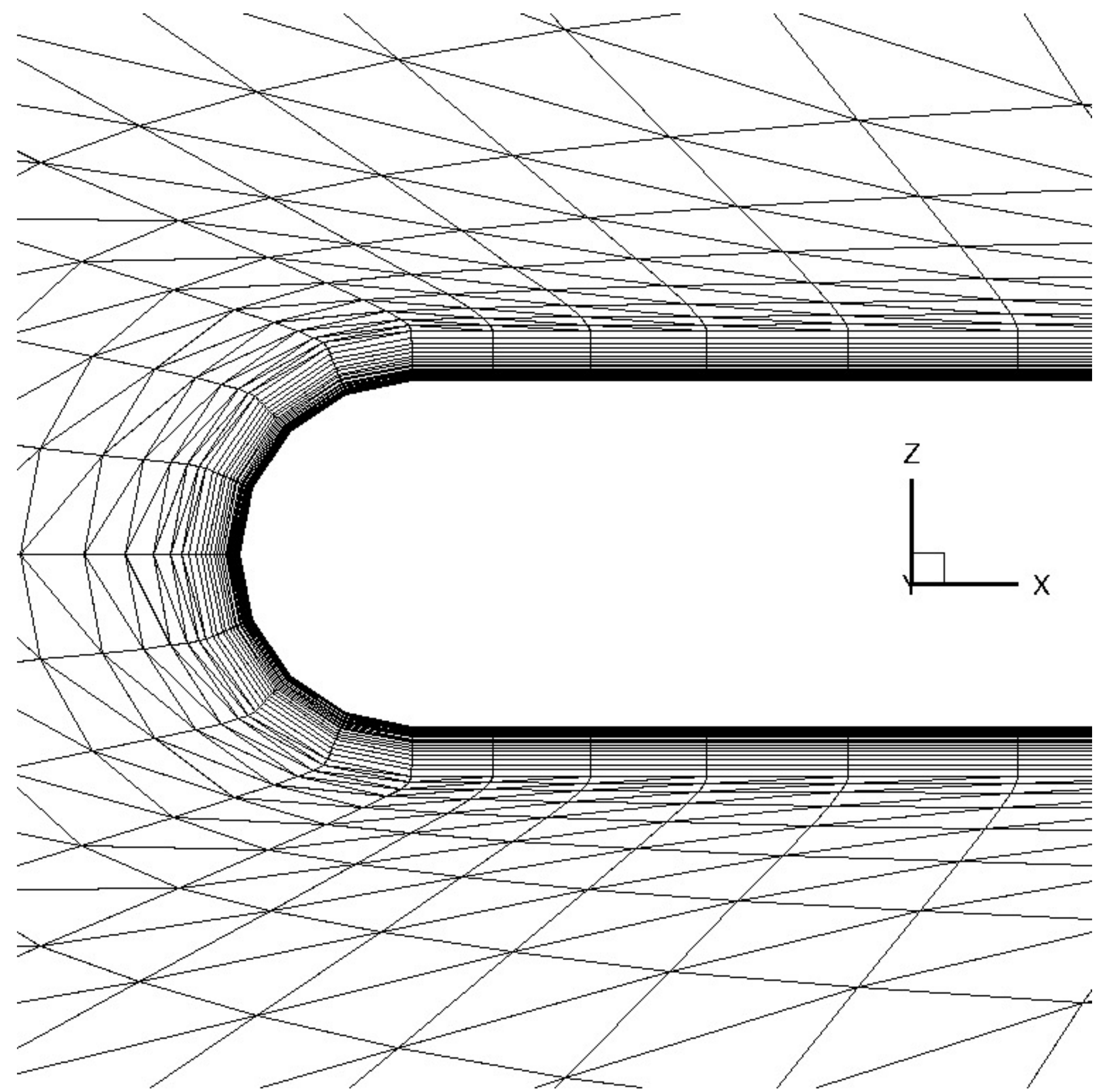
Symmetry plane



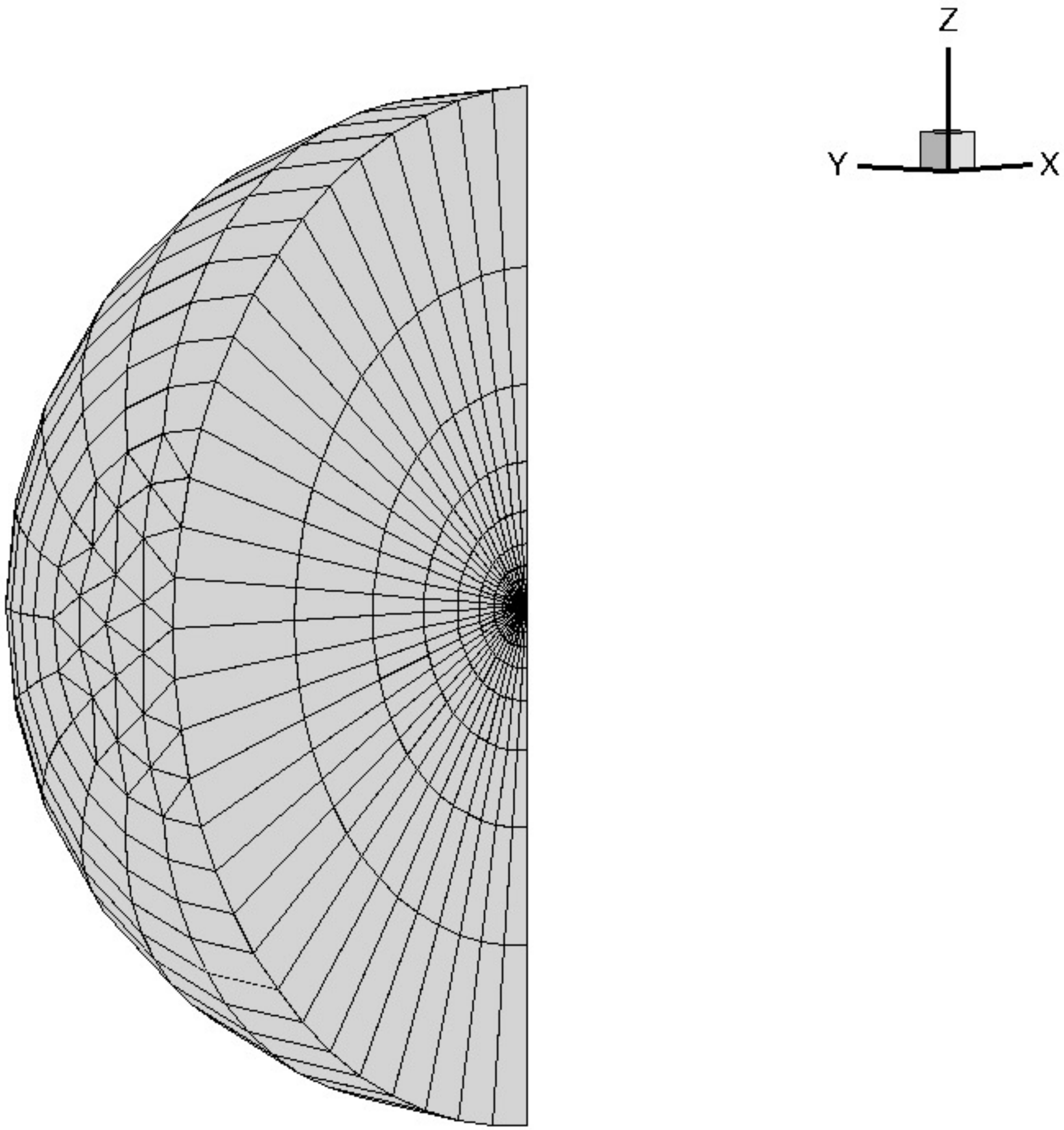
Half: Prism-Tetra



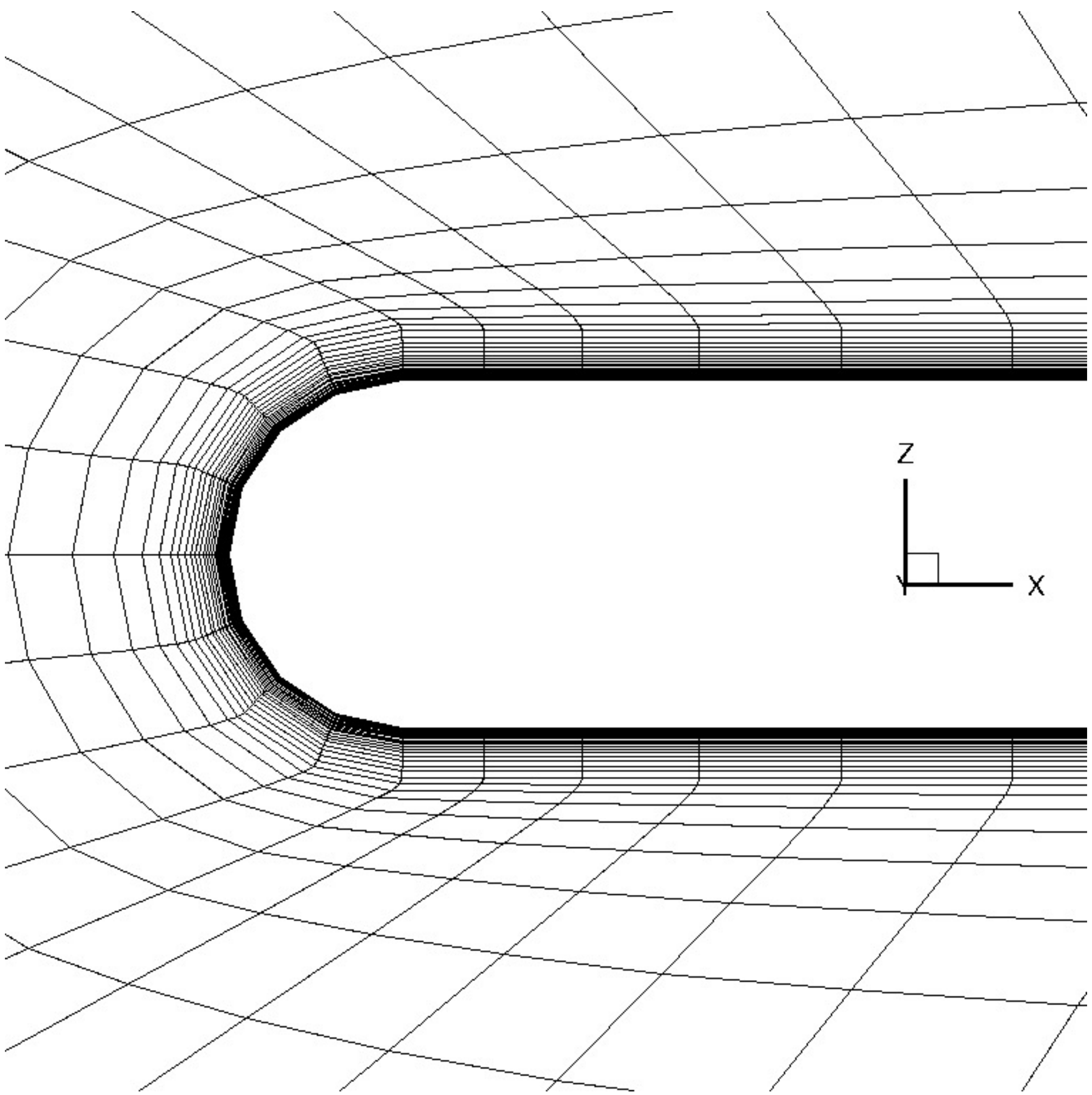
Symmetry plane



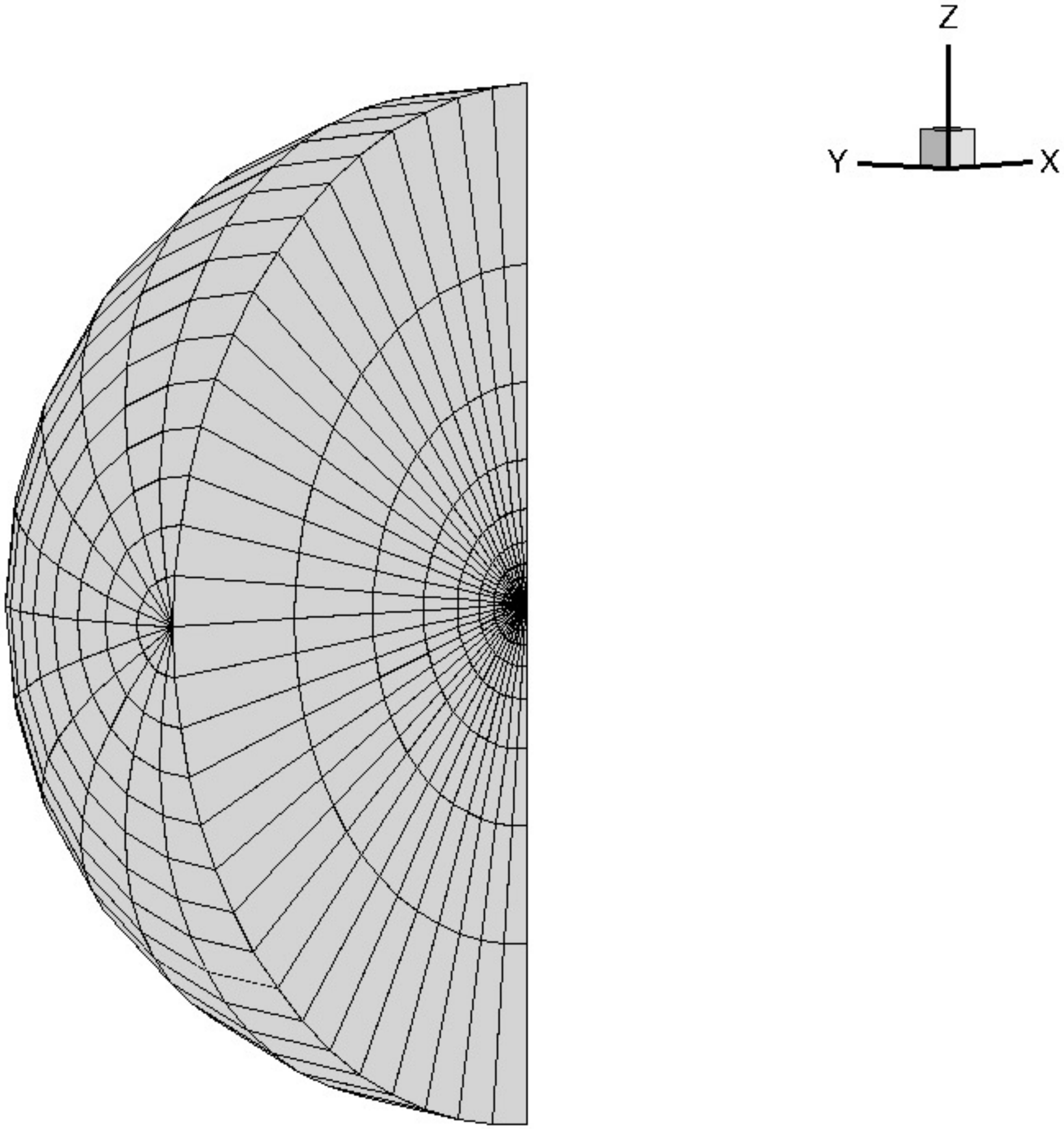
Half: Prism-Hex



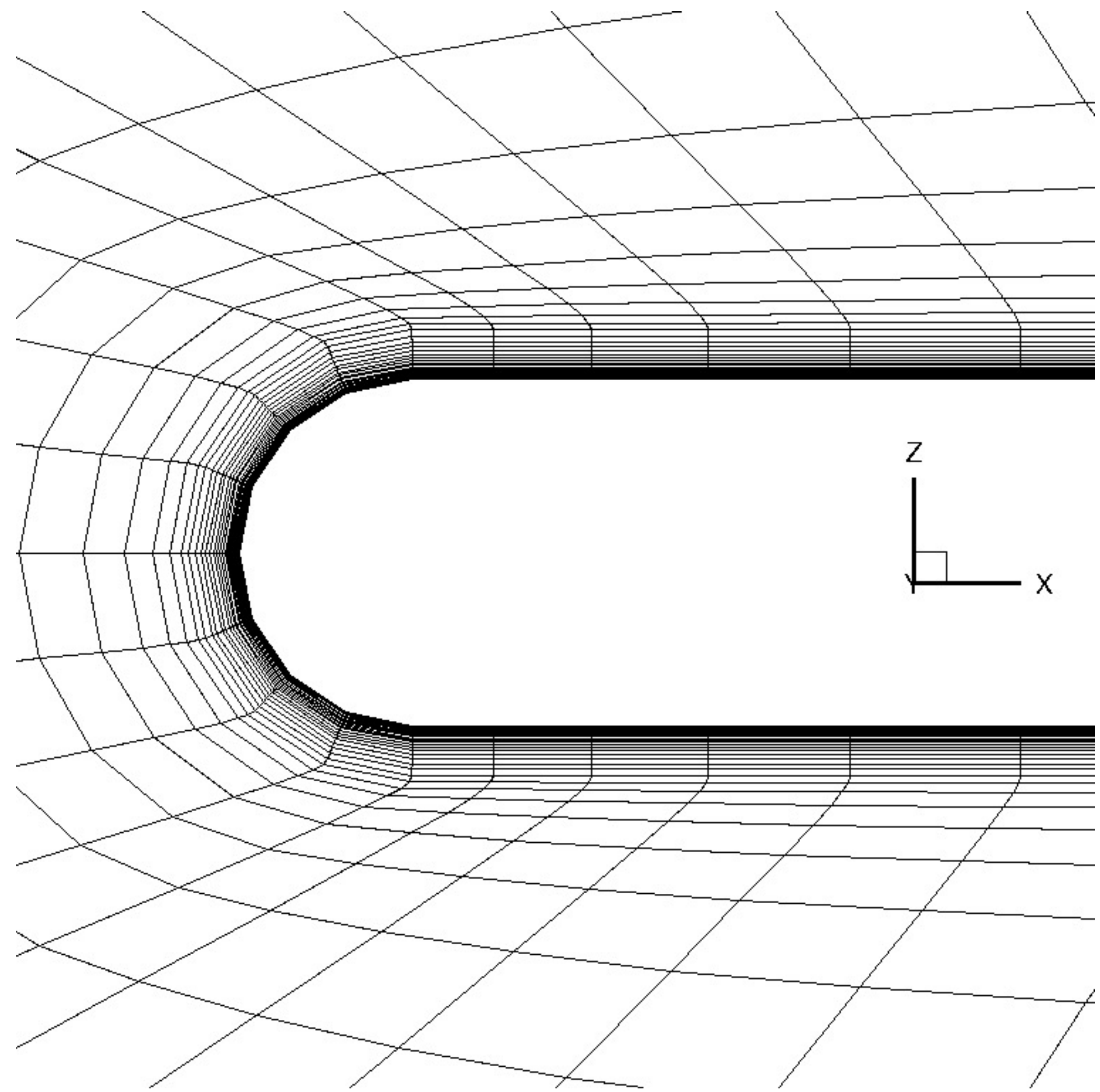
Symmetry plane



Half: Structured (Hex+prism)



Symmetry plane



Package

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Download hc_v7p5_release_light.tar.gz at TMR website:

HC: NASA Langley TMR website

%tar -xvf hc_v7p5_release_light.tar.gz

- hcf_hc_v7p5.f90
- hcf_coarsening_v2p1.f90
- readme_release_light.txt
- sample_input , sample_input_coarsen
- sample_input_tets, sample_input_tets_coarsen

%source readme_release_light.txt

Sample structured grids and tetrahedral grids are generated.

readme_release_light.txt

> Compile the codes

```
gfortran -o hcf_hc            hcf_hc_v7p5.f90
gfortran -o hc_coarsening  hcf_coarsening_v2p1.f90
```

```
#-------------------------------------------------------------------
# Endianness will be automatically detected, but if you wish,
# you can specify endianness at compilation: e.g., as follows:
#  gfortran -O2 -fconvert=big-endian -o hcf_hc  hcf_hc_v7p5.f90
#        ifort -O2 -convert big_endian  -o hcf_hc  hcf_hc_v7p5.f90
#-------------------------------------------------------------------
```

> Generate a structured grid

```
hcf_hc < sample_input
```

> Generate coarser grids

```
hc_coarsening < sample_input_coarsen
```

> Generate a tetrahedral grid

```
hcf_hc           < sample_input_tets
```

> Generate coarser grids

```
hcf_coarsening < sample_input_tets_coarsen
```

Input parameters

"sample_input" in hc_v7p5_release_light.tar.gz

```
350000    !Target Reynolds number
1         !Target y-plus value
5         !Element-type: 1=prsm, 2=tets, 3=prsm/tets, 4=prsm/hex, 5=Strct
T         !T = unformatted .ugrid/.ufmt, F = formatted .ugrid/.p3d
100       !Distance to outer boundary (=radius of the outer hemisphere)
48        !Elements along the cylinder
10        !Length of hemisphere-cylinder (apex to base = x2)
16        !Elements along the hemisphere (x=0 to 0.5)
256       !Elements in the radial direction
2         !1: full geometry, 2: a half domain (y > 0 only).
T         !T = Write a boundary grid (Tecplot)
F         !T = Write a volume grid (Tecplot)
T         !T = Write a 'k'-file (required by the coarsening program)
T         !T = Write line files (e.g., for line-relaxation)
T         !T = Write .ugrid file (any type of grid)
T         !T = Write .p3d/.umft and .nmf files (igrid_type = 5 only).
```

Note: Items in red are required for regular coarsening.

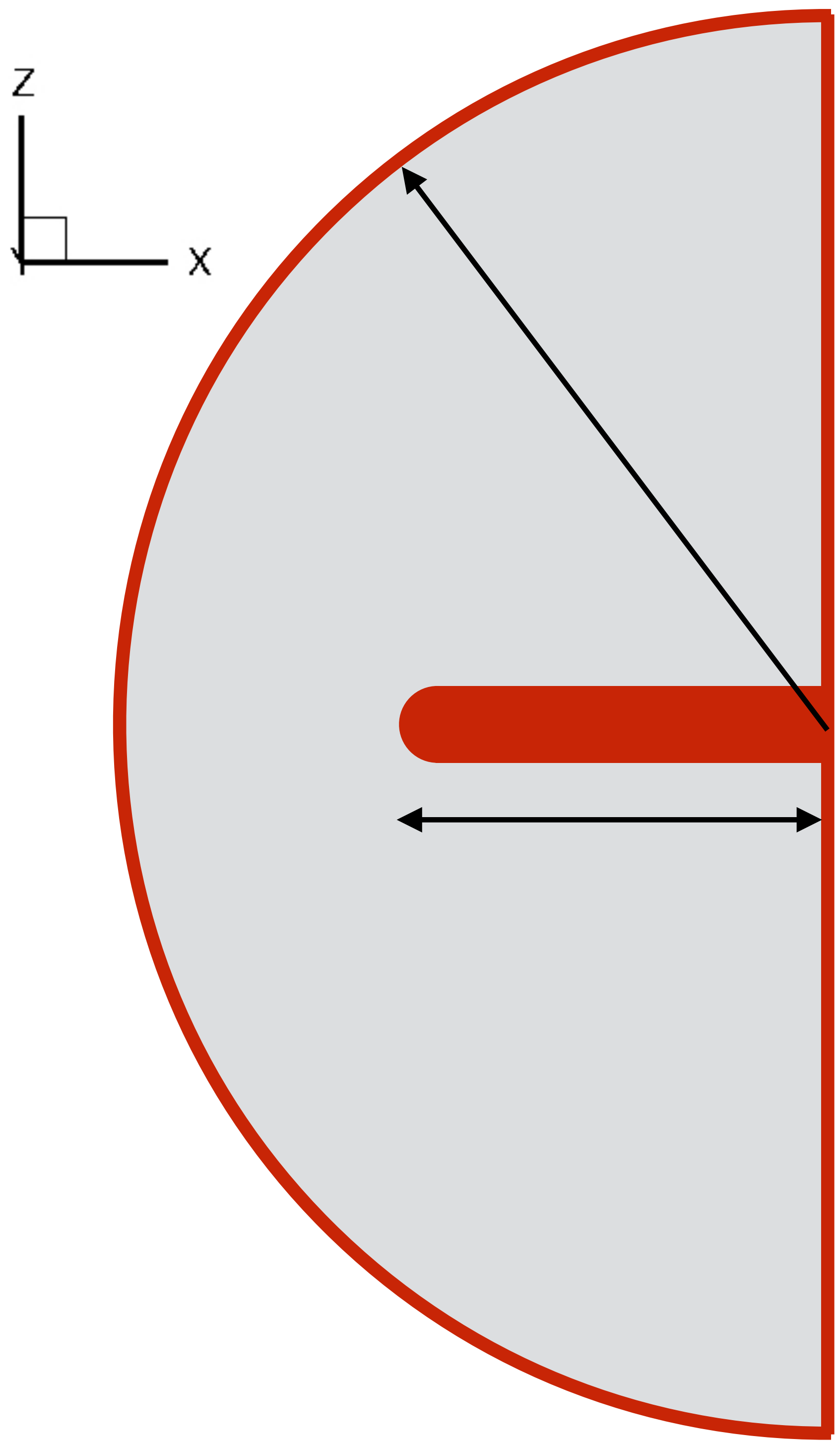
Typical Output

.ugrid/p3d(.ufmt) : Grid file
.mapbc : BC file

.lines_fmt : List of nodes in lines within the BL region
.lines_fmt_all : List of all nodes in lines to the outer boundary.
.k : Structured index file (for coarsening)

Tecplot boundary/volume files.

Geometry



Hemisphere outer boundary:

Radius of the hemisphere (input)

Hemisphere-cylinder:

Apex at the origin
Radius of the hemisphere = 0.5
Length of the HC$_{\text{=x-coordinate of the base center}}$ (input)

Grid size parameters

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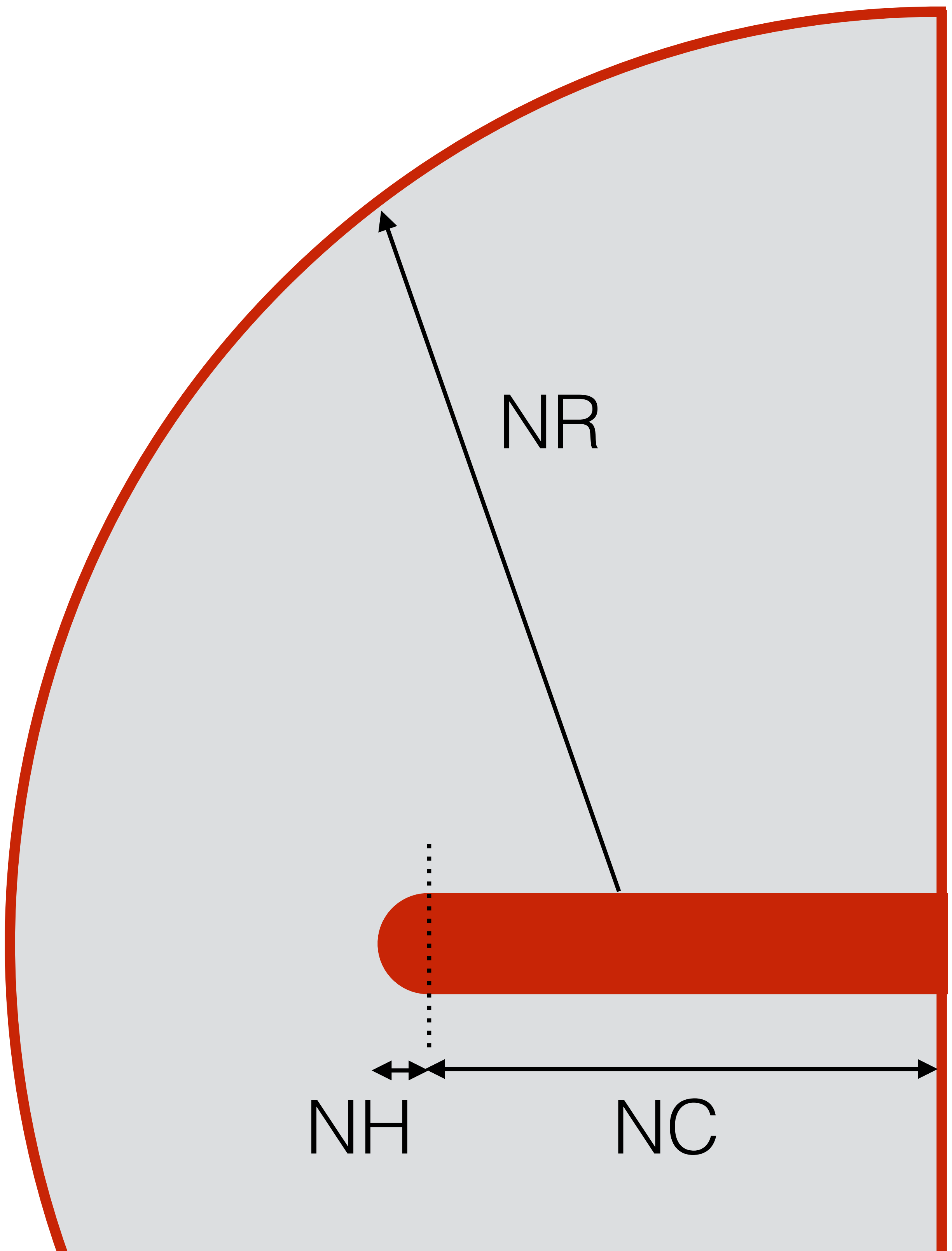


Three input parameters.

NC !# of Elements along the cylinder
NH !# of Elements along the hemisphere
NR !# of Elements in the radial direction

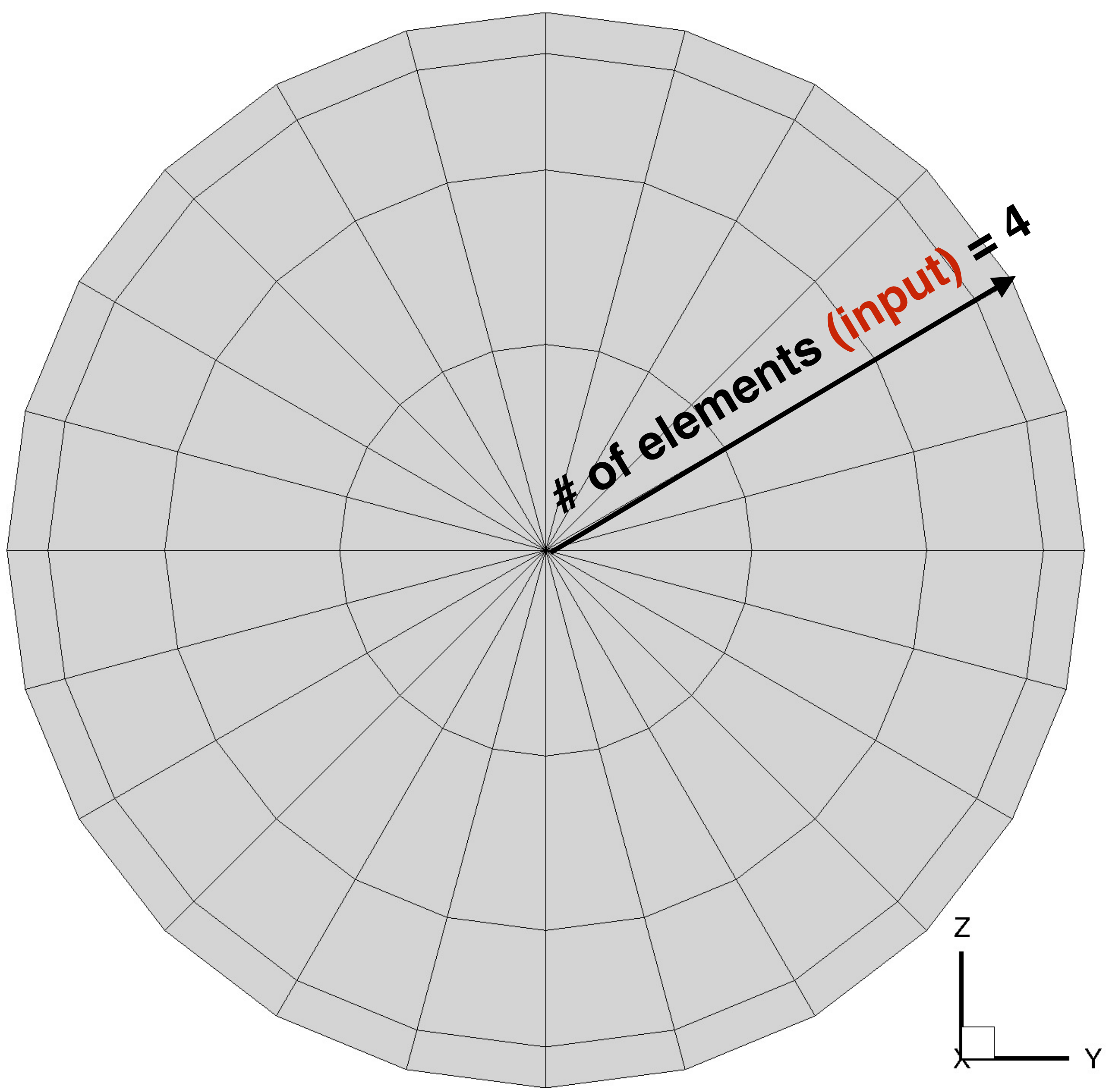
Other input parameters.

Re !Target Reynolds number
y_plus !Target y-plus value

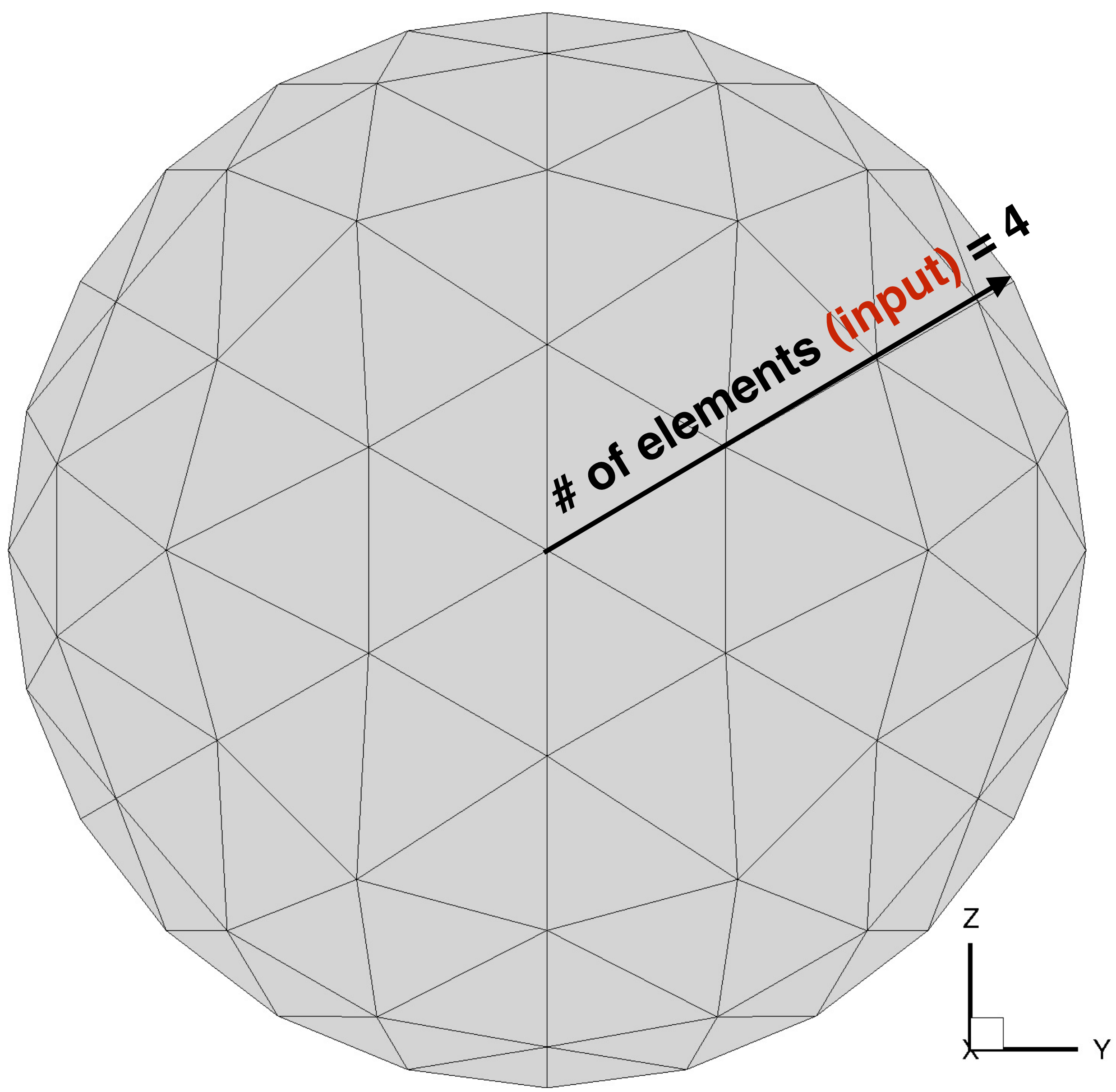
Grid size of the BL region is determined inside the code based on these parameters.

Hemisphere grid

Structured grid
Hex+prisms

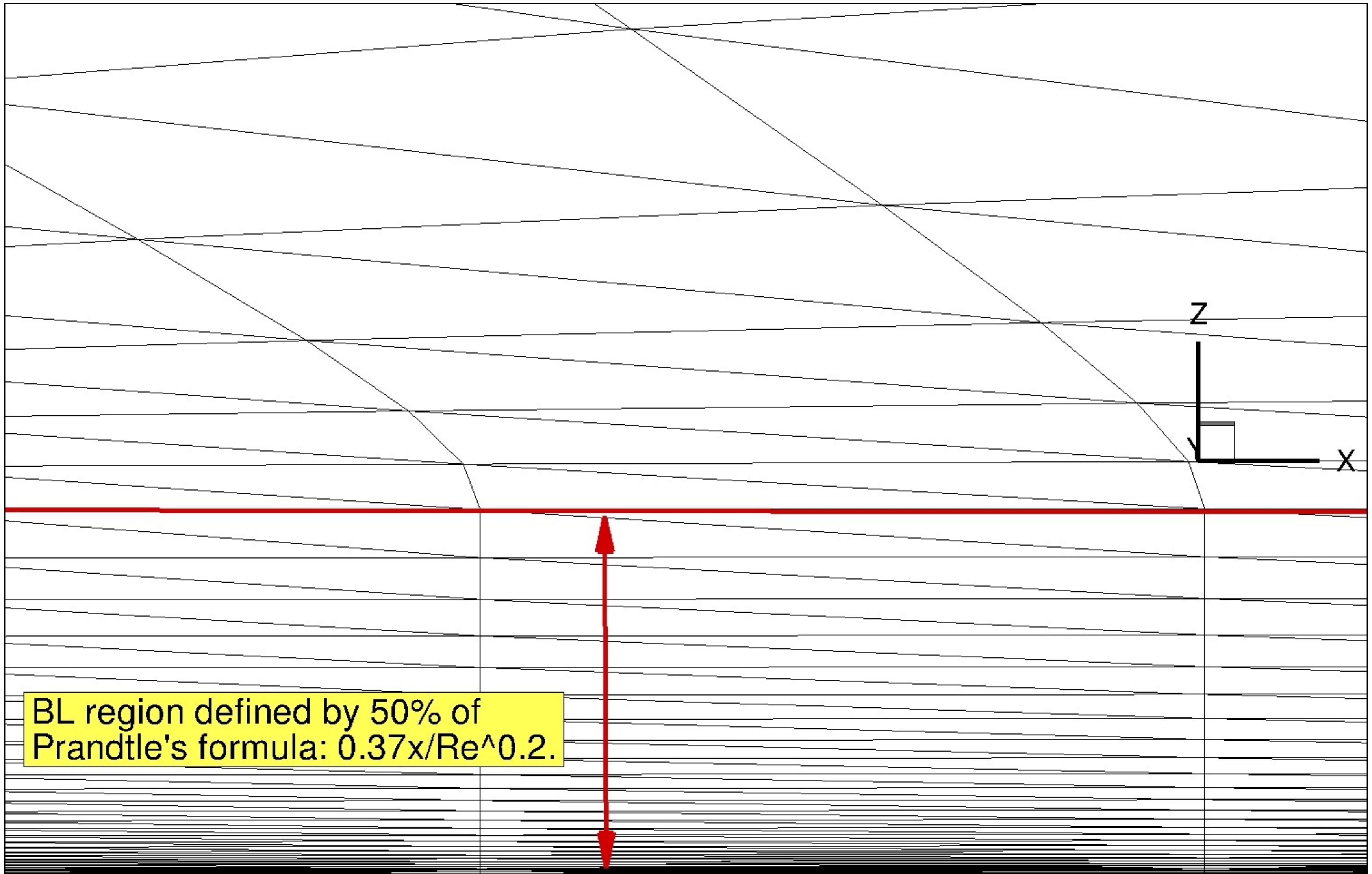


Unstructured grid
Prism/Tetra/Mixed1/Mixed2



Elsewhere, nodes are generated by the same algorithm.

Grid spacing: BL region



First-Off-The-Wall spacing = dr1 is determined for a target y+:
dr1 = target_y_plus*(sqrt(2*cf)/Re), cf = 0.026/Re^(1/7)

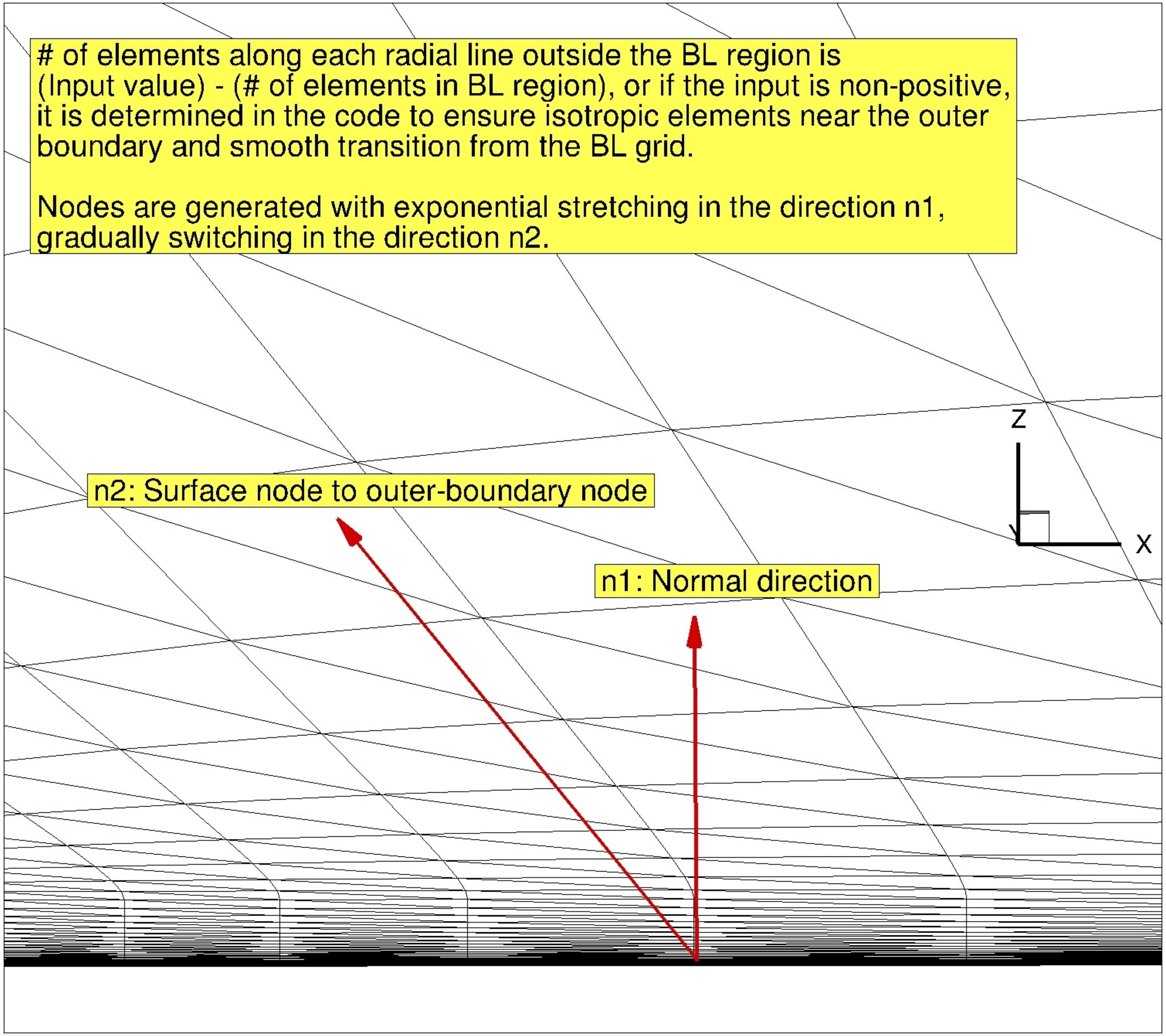
Nodes in the BL region is determined by a geometric sequence to achieve the outer spacing of 10% of a surface grid spacing.

Target Re (input)
Target y+ (input)

BL region thickness is constant over the surface. It has been checked to fully contain boundary layers for intended Reynolds numbers.

y+ will increase progressively for coarser grids generated by regular coarsening (removing every other node).

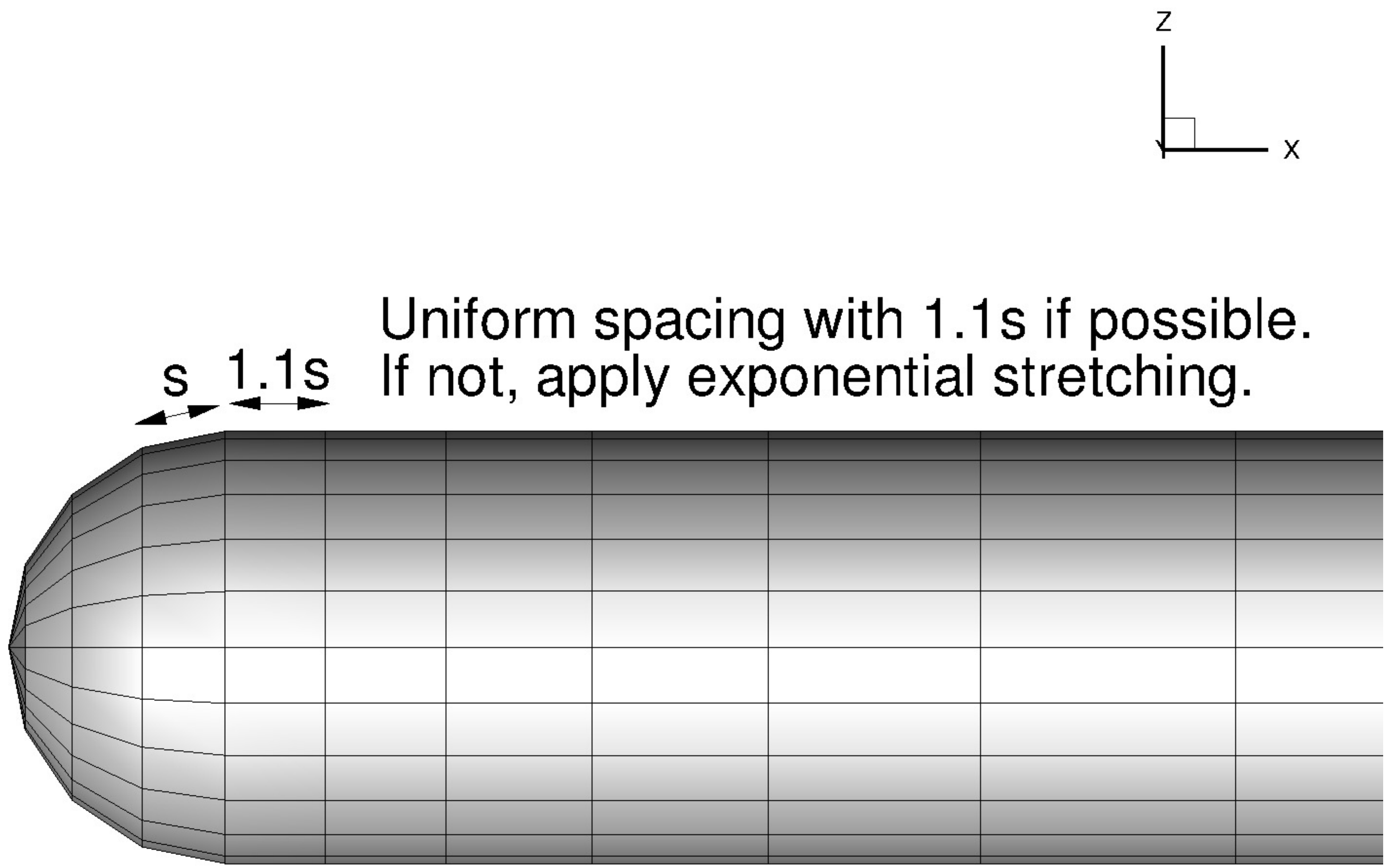
Grid spacing: outer region



of *total* elements in the radial direction (input)

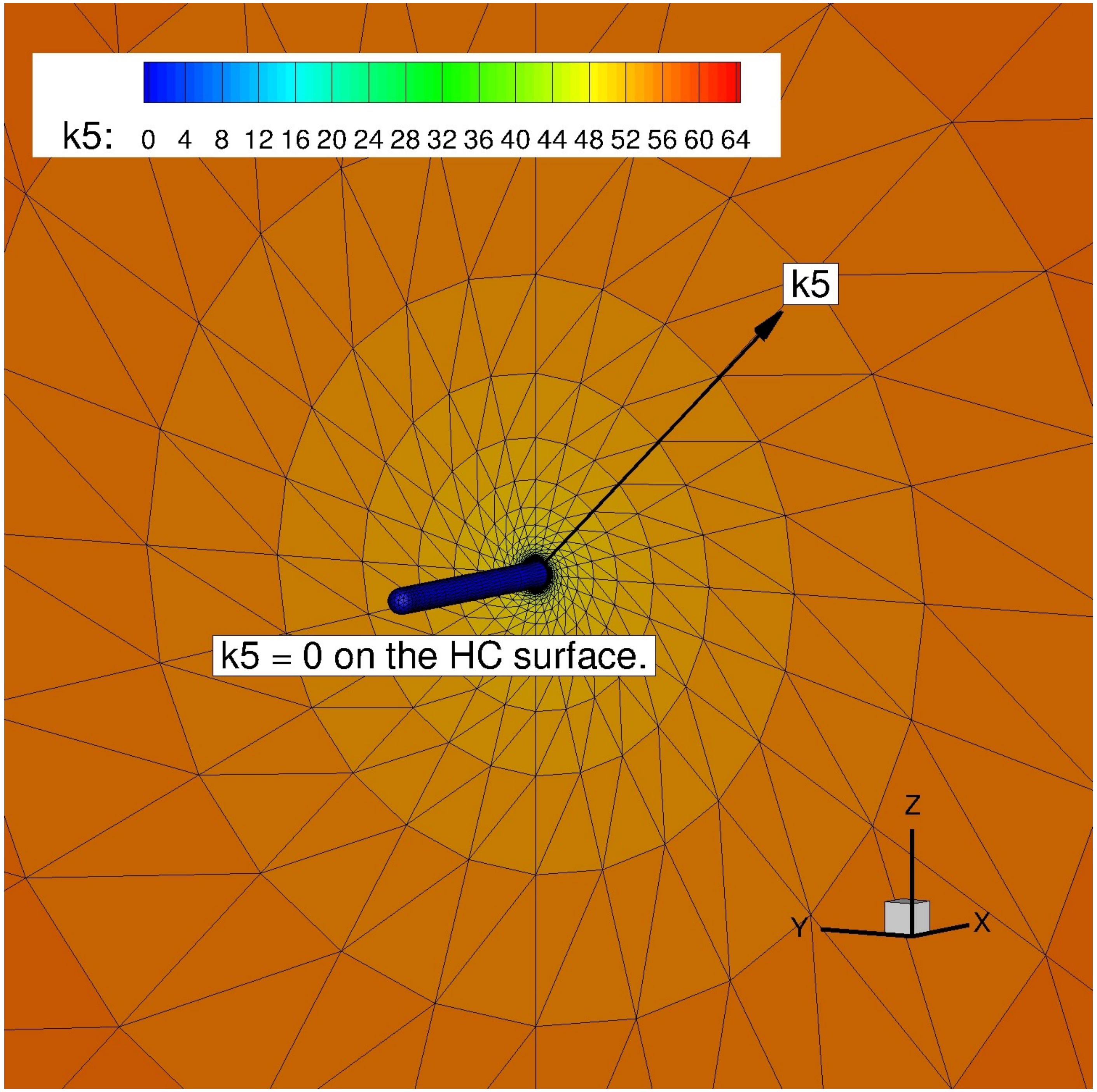
Input value must be large enough, or the code stops and asks you to try again with a suggested value.

Grid spacing: cylinder surface



Common Structured Index: k5

Nodes have structured indices: (k1,k2,k3,k4,k5): **k5 is common to all grids.**



Structured Indices: k1, k2, k3

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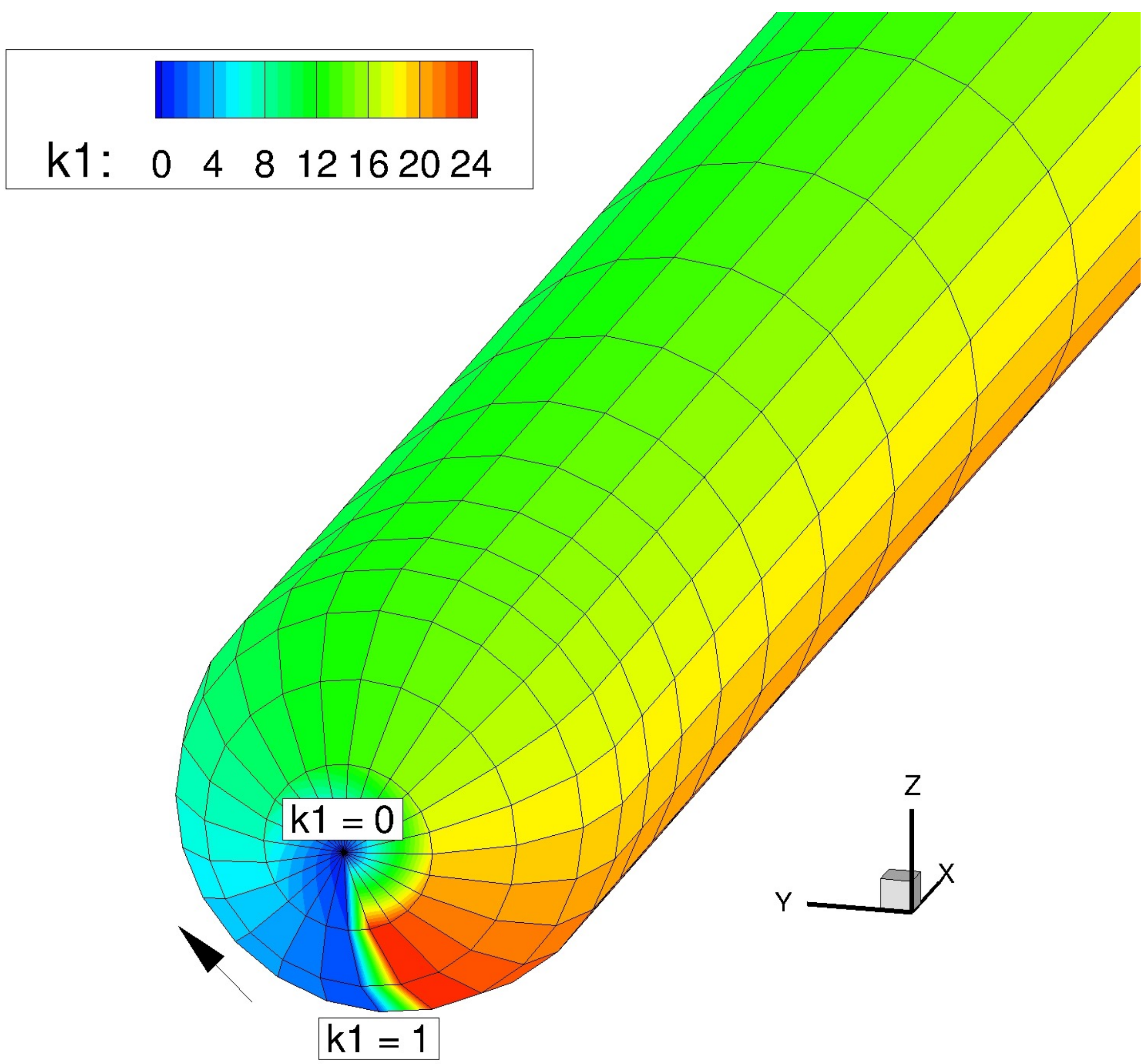
Structured grid

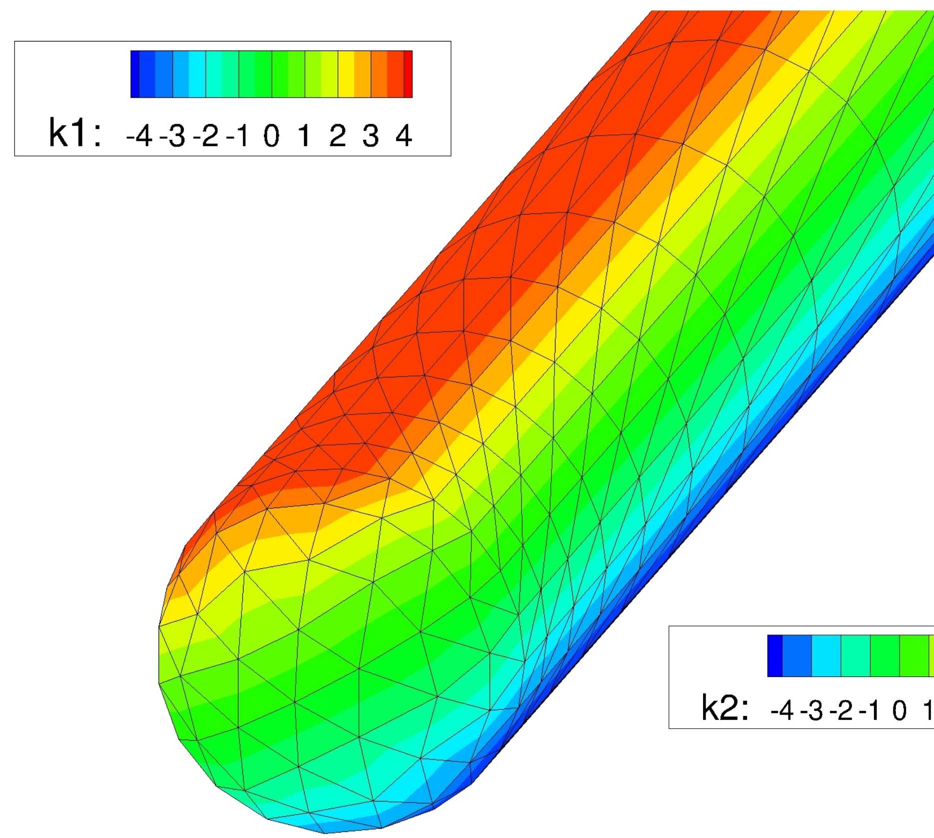
Hex+prisms

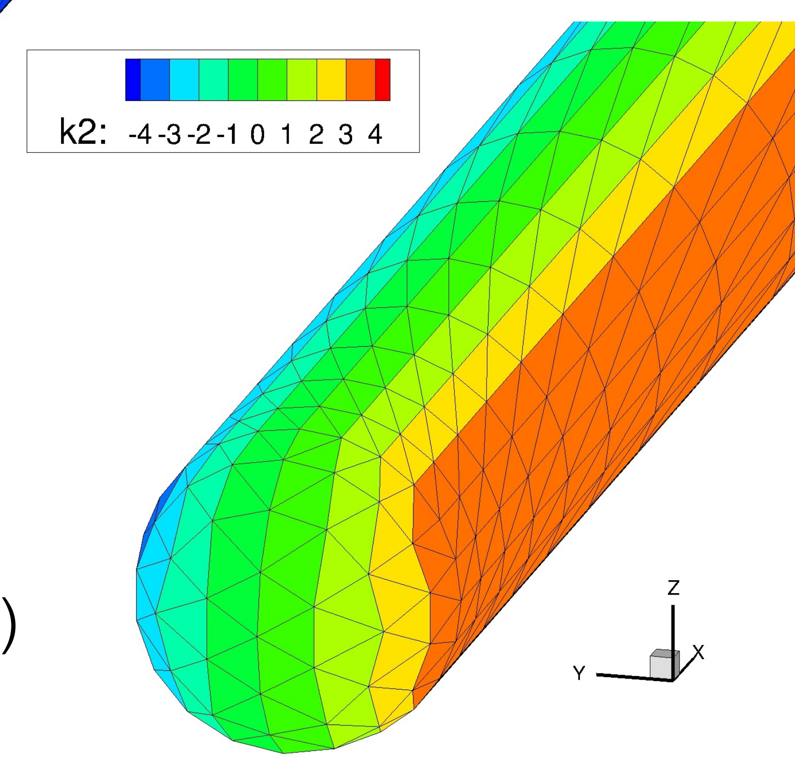


k2 and k3 not used in structured grids.

Unstructured grid

Prism/Tetra/Mixed1/Mixed2



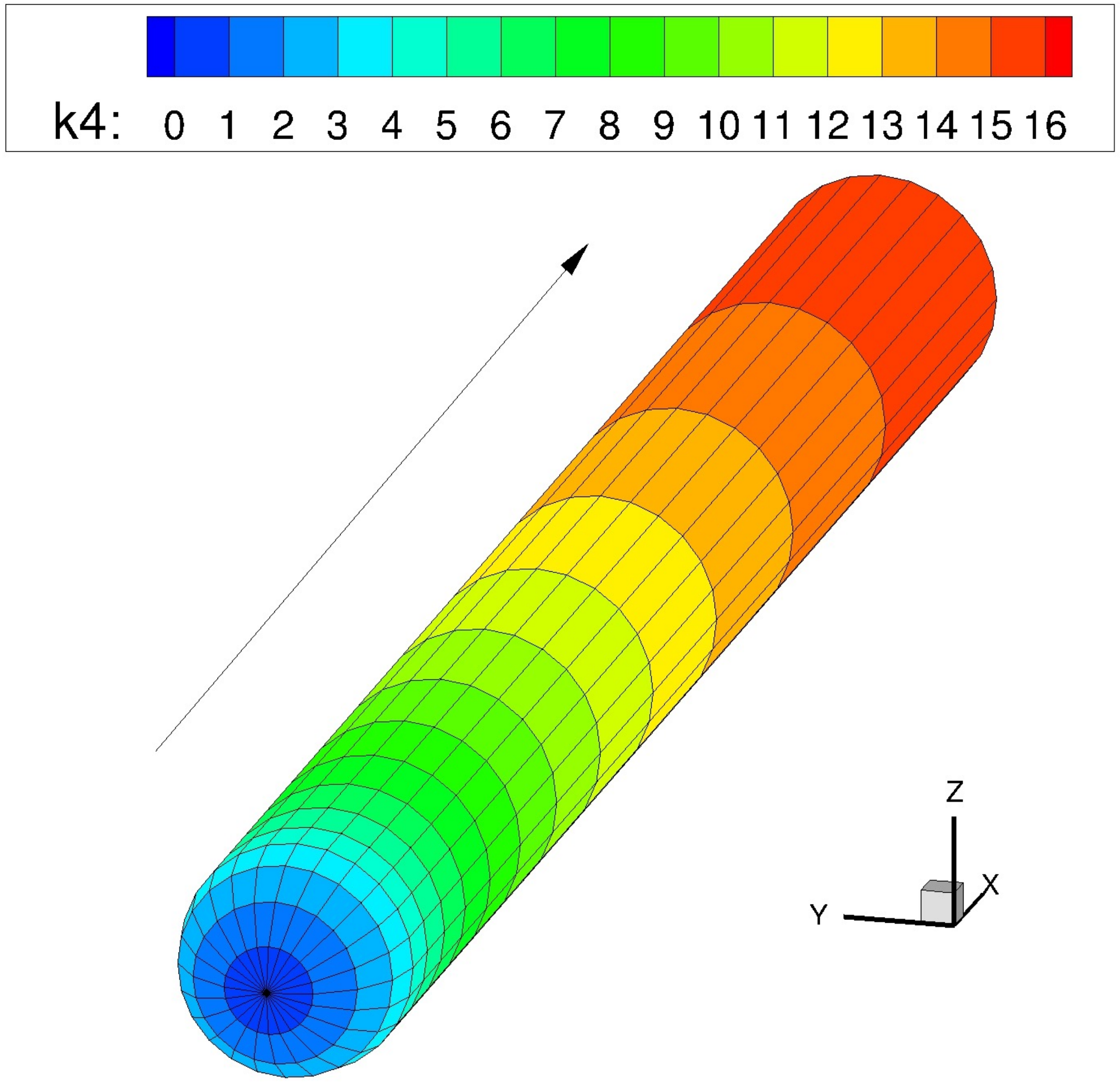


k3 = -(k1+k2)

Structured Index k4

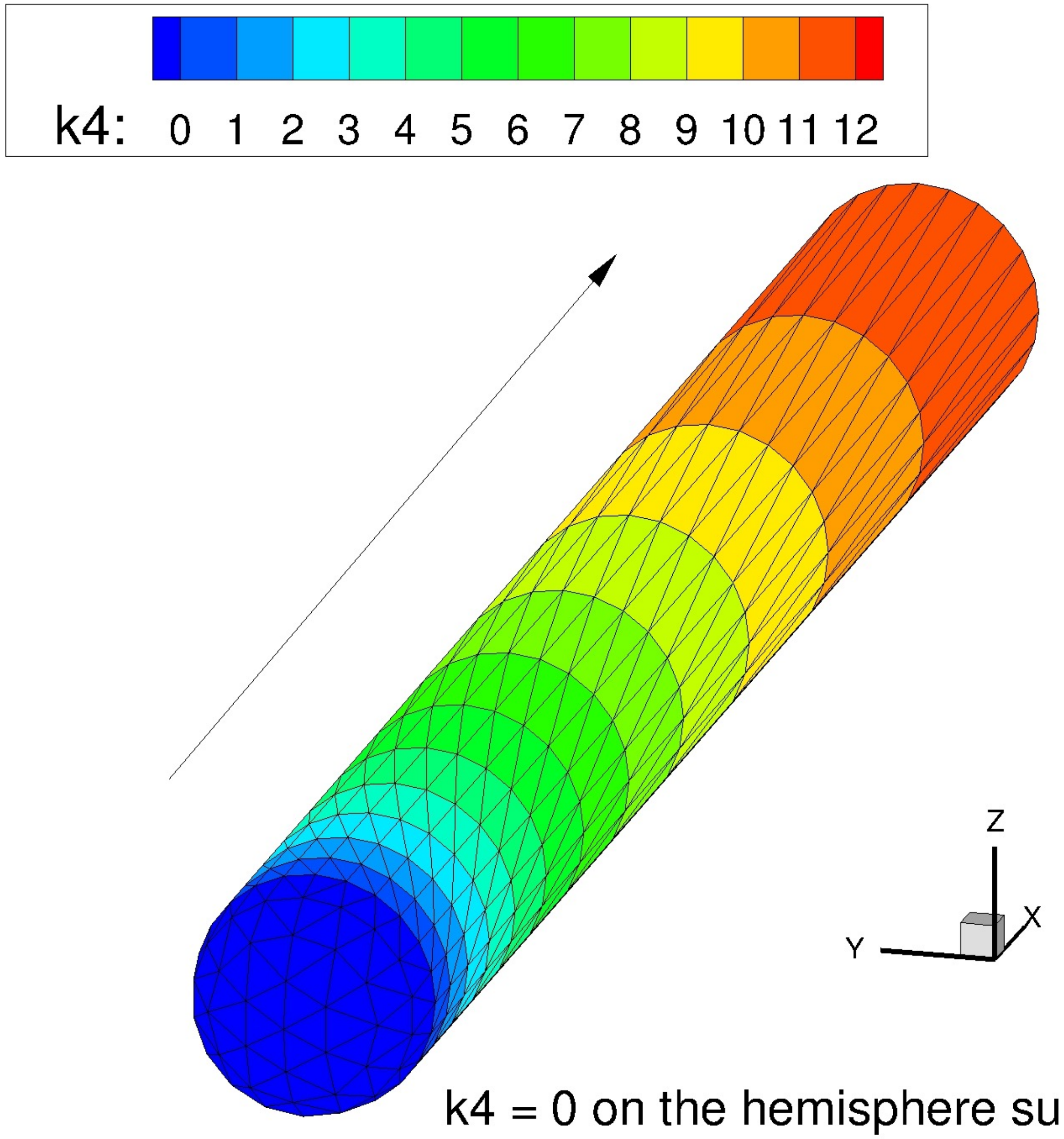
Structured grid

Hex+prisms



Unstructured grid

Prism/Tetra/Mixed1/Mixed2



k4 = 0 on the hemisphere surface.

Lines

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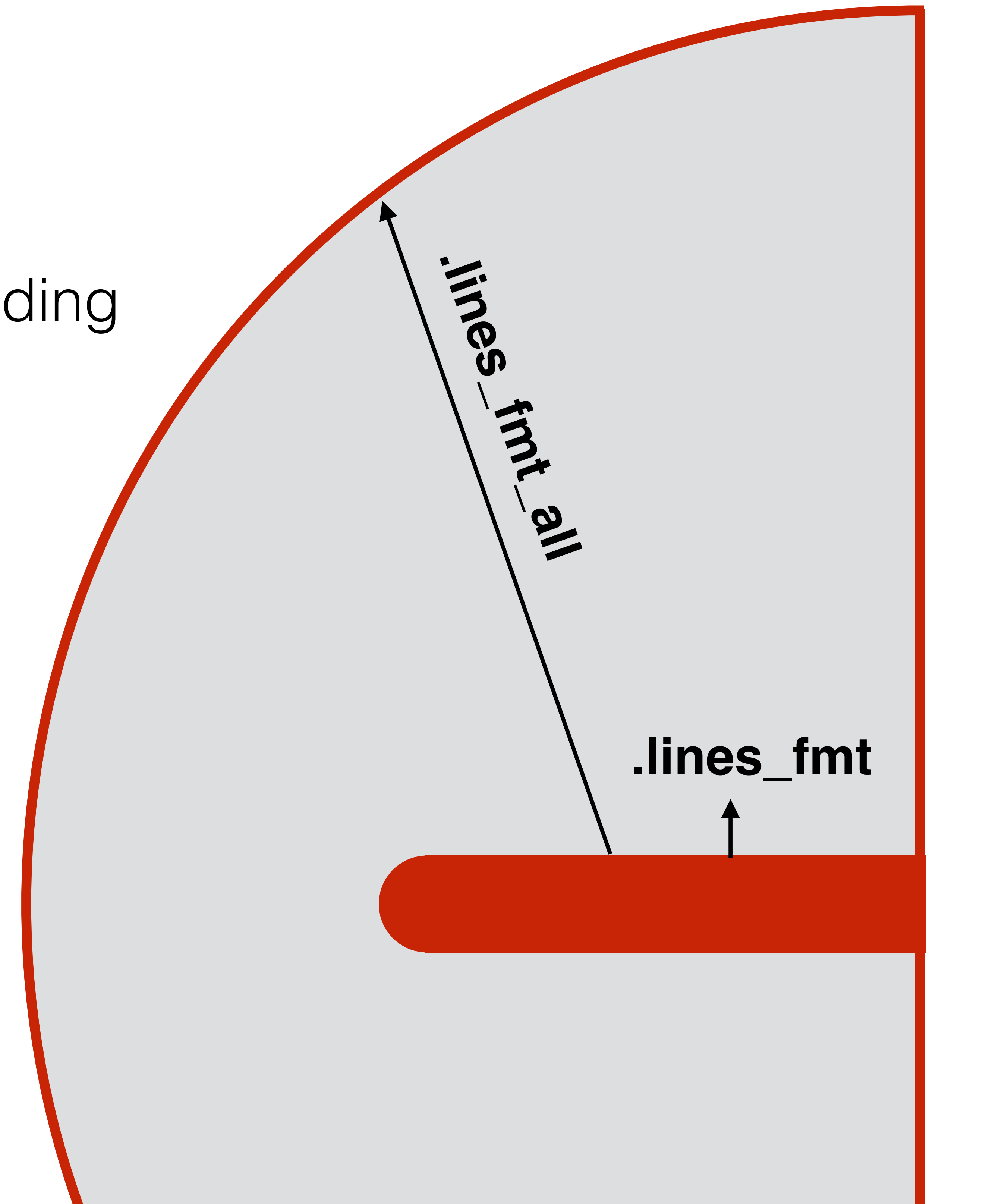
.lines_fmt_all:

List of nodes in the radial grid lines
from surface nodes to the corresponding
outer-boundary nodes.

.lines_fmt:

List of nodes in lines within
the BL region.

can be used for line-agglomeration,
line-relaxation.



3D Wing Grids

Topologically equivalent to HC grids

`hcf_wing_v3p3.f90`

Topologically Equivalent to HC

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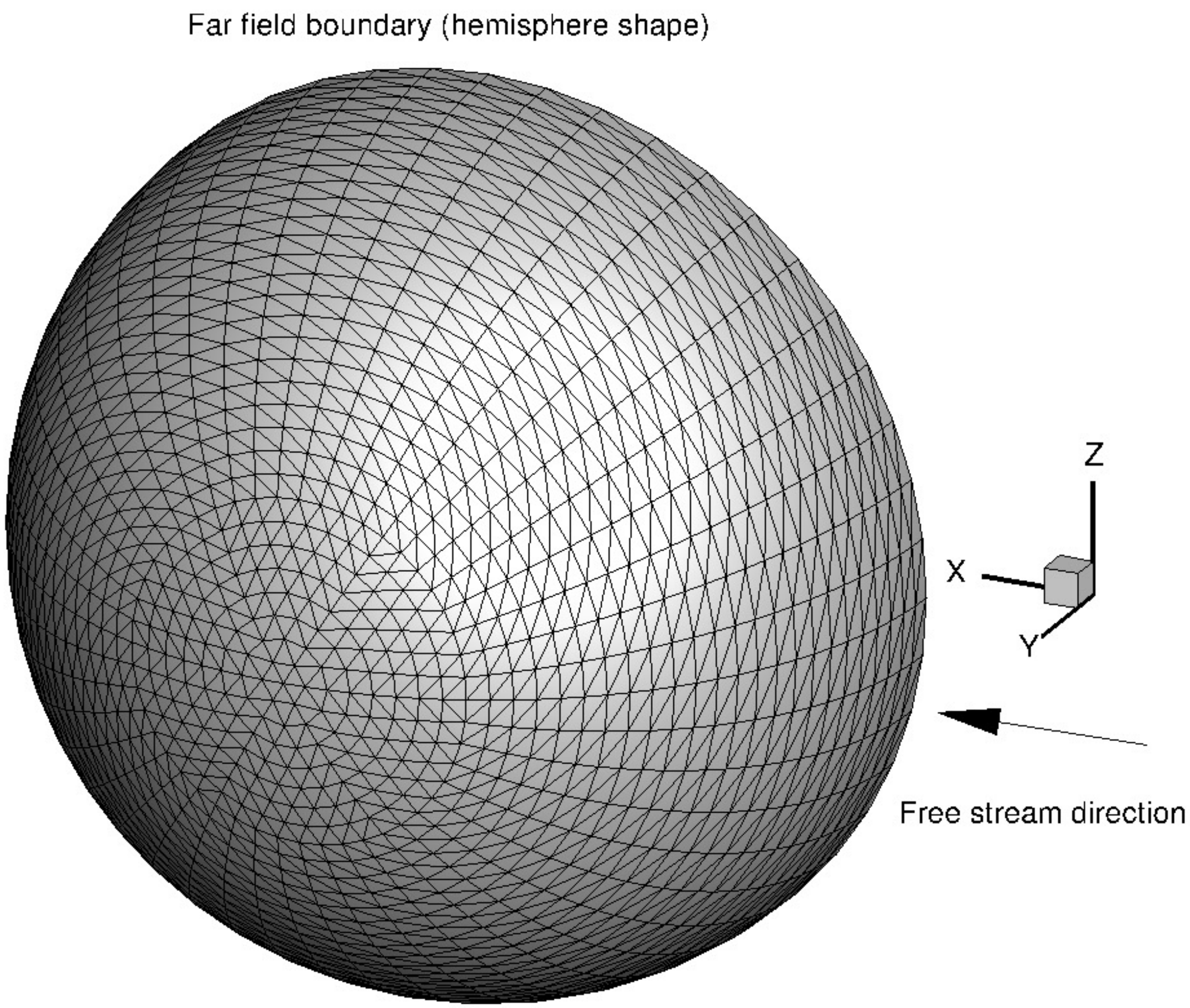
Wing grid is generated by mapping a full-geometry HC onto a wing with a specified wing section:

Hemisphere -> Round tip (rotated wing section)
Cylinder -> Wing surface
(Far-field surface mesh is the same between HC and wing.)

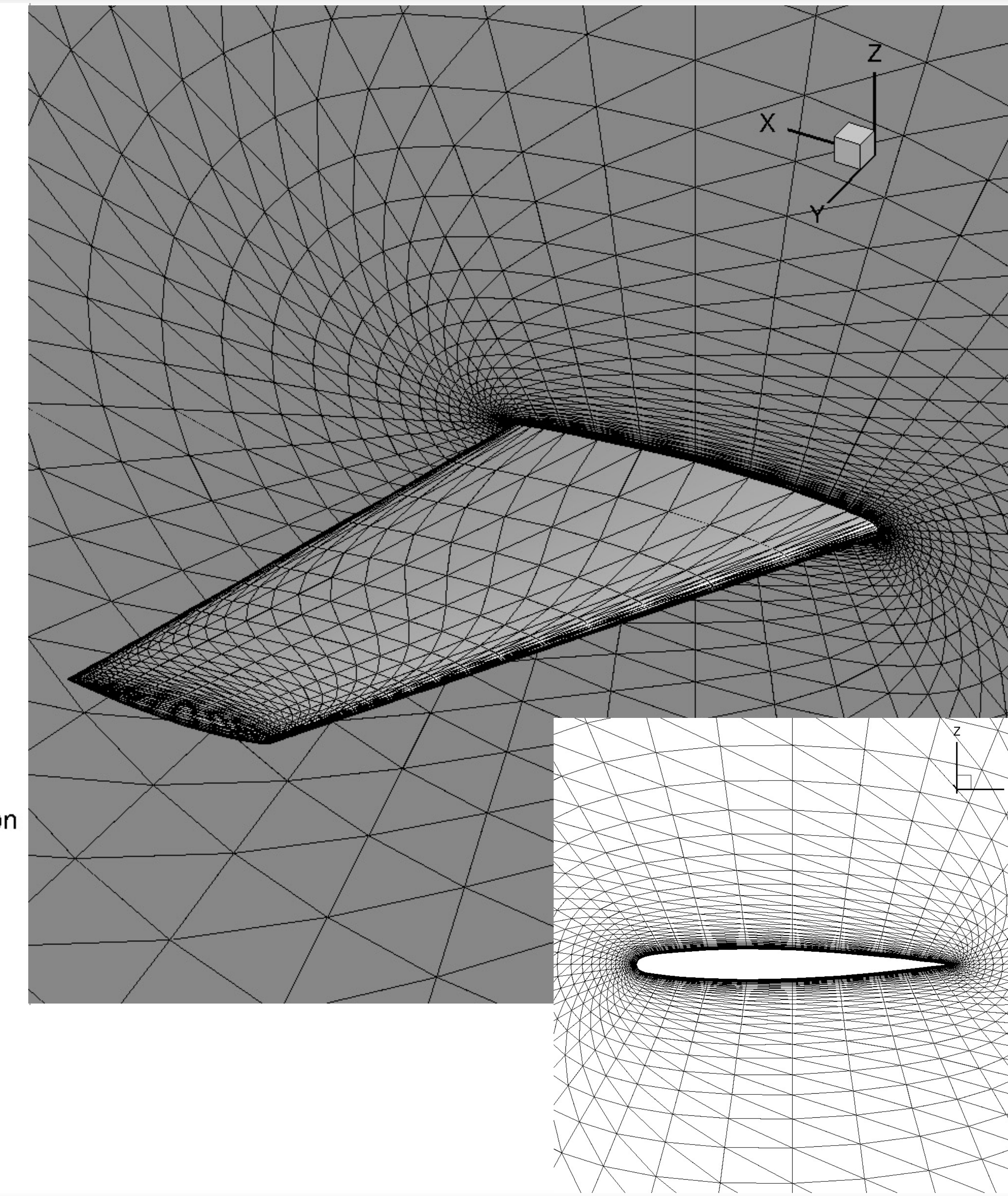
Wing section can be specified by the last two digits of NACA00XX or by a set of discrete points.

The grid is topologically equivalent to a HC grid. Input values, node generation, line information, and structured indices are the same as the HC grid case.

Tetra

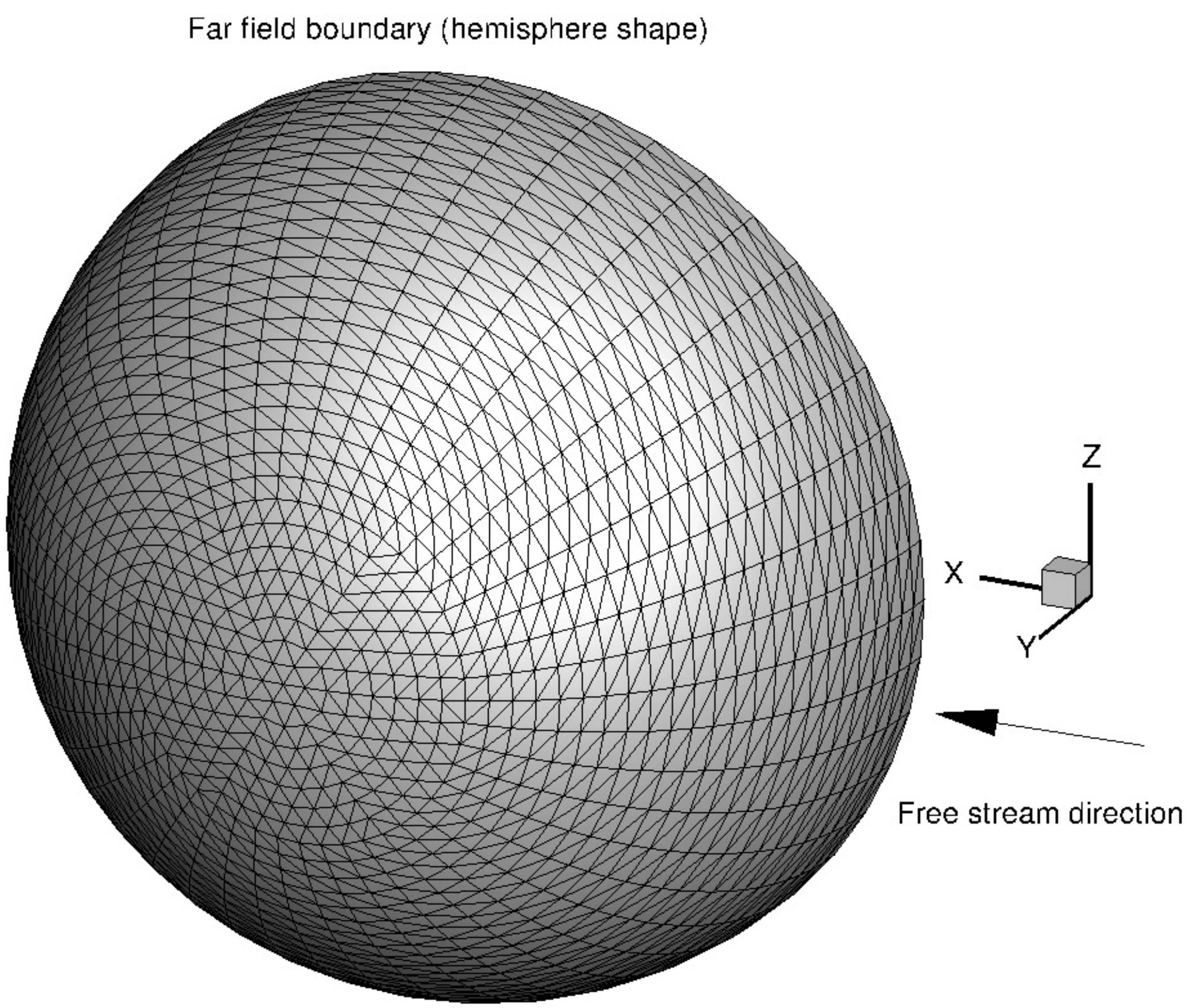


Far field boundary (hemisphere shape)
Z
X
Y
Free stream direction

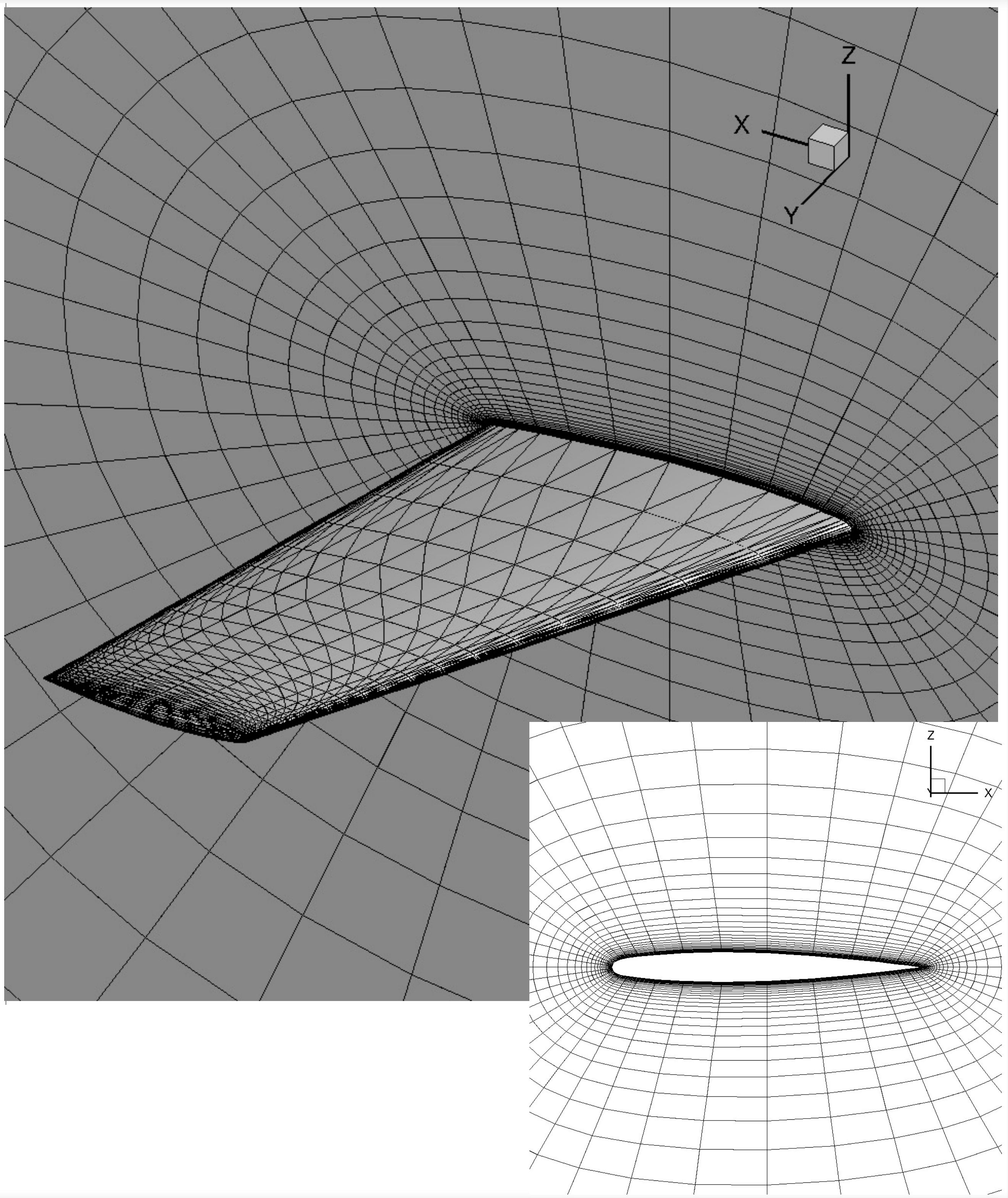


Z
X
Y

Prism

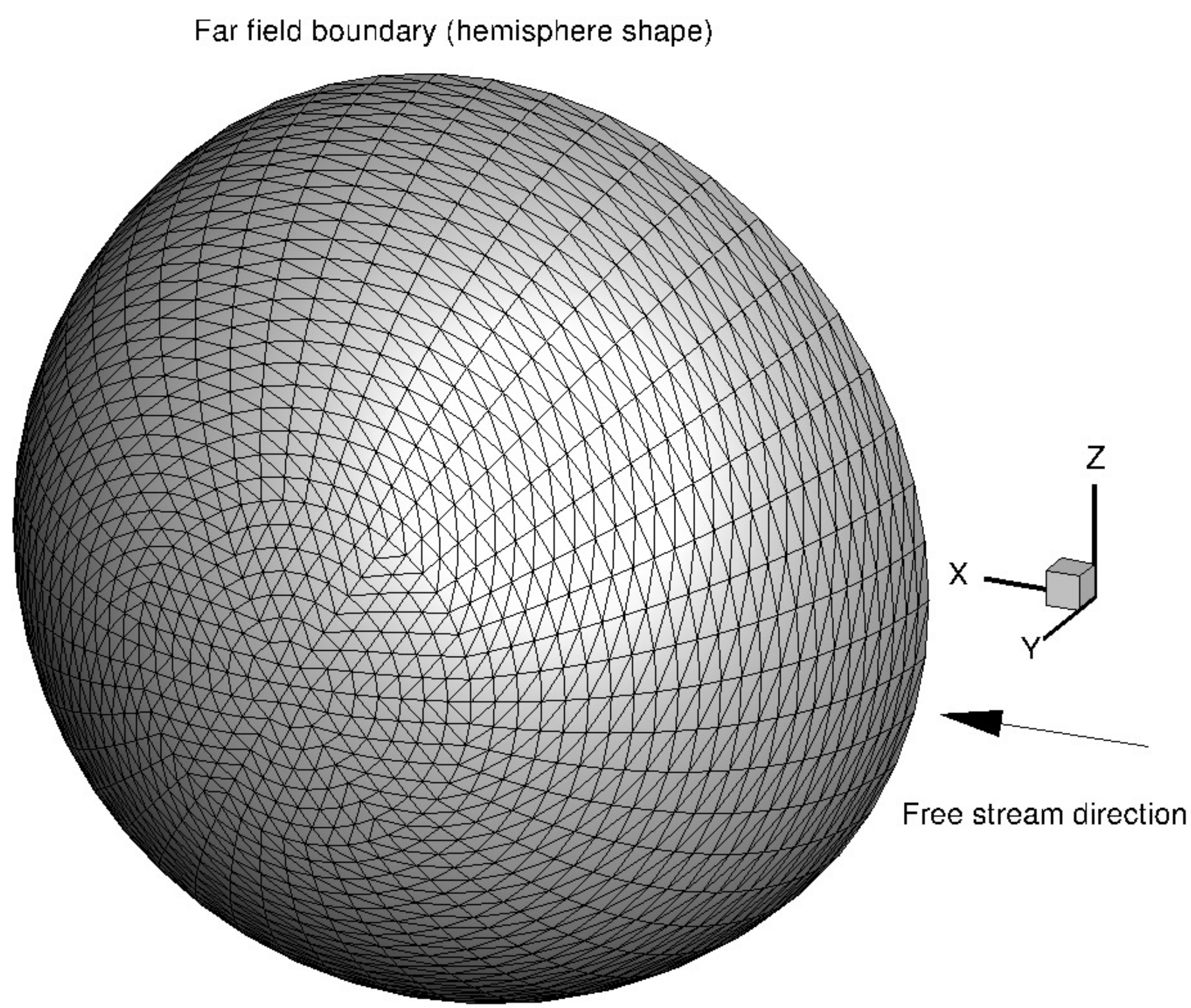


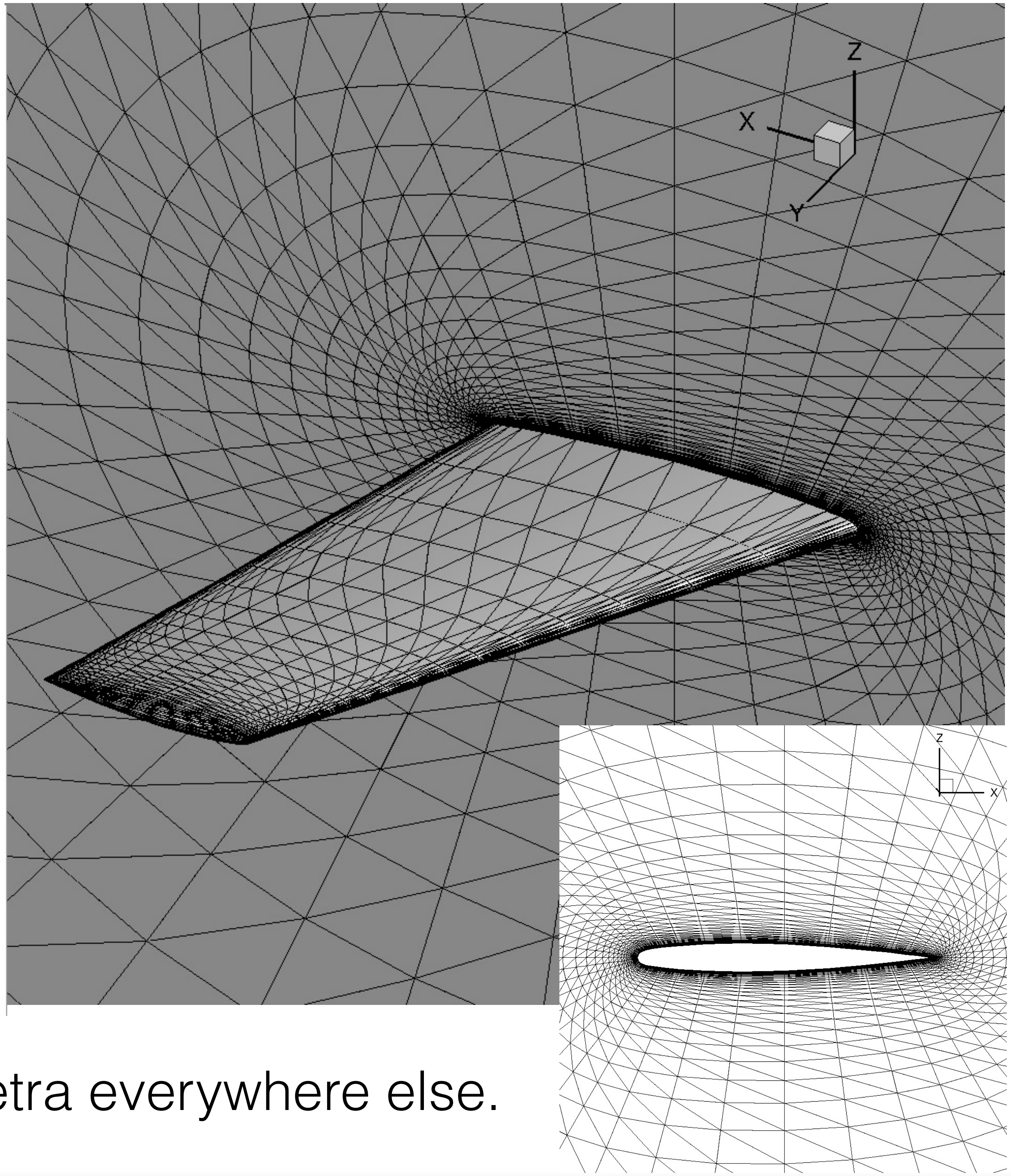
Far field boundary (hemisphere shape)
Z
X
Y
Free stream direction



Z
X
Y

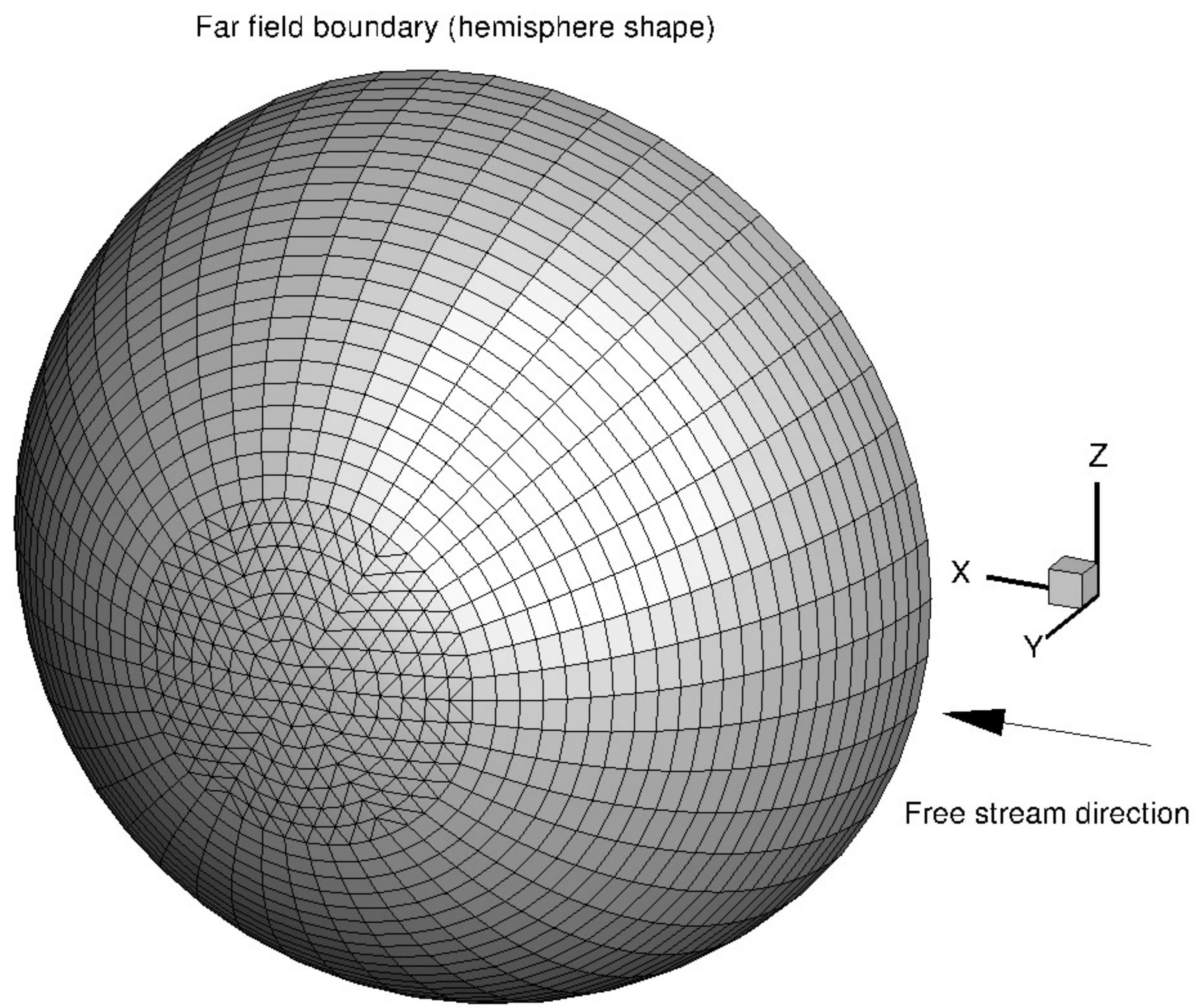
Prism-Tetra

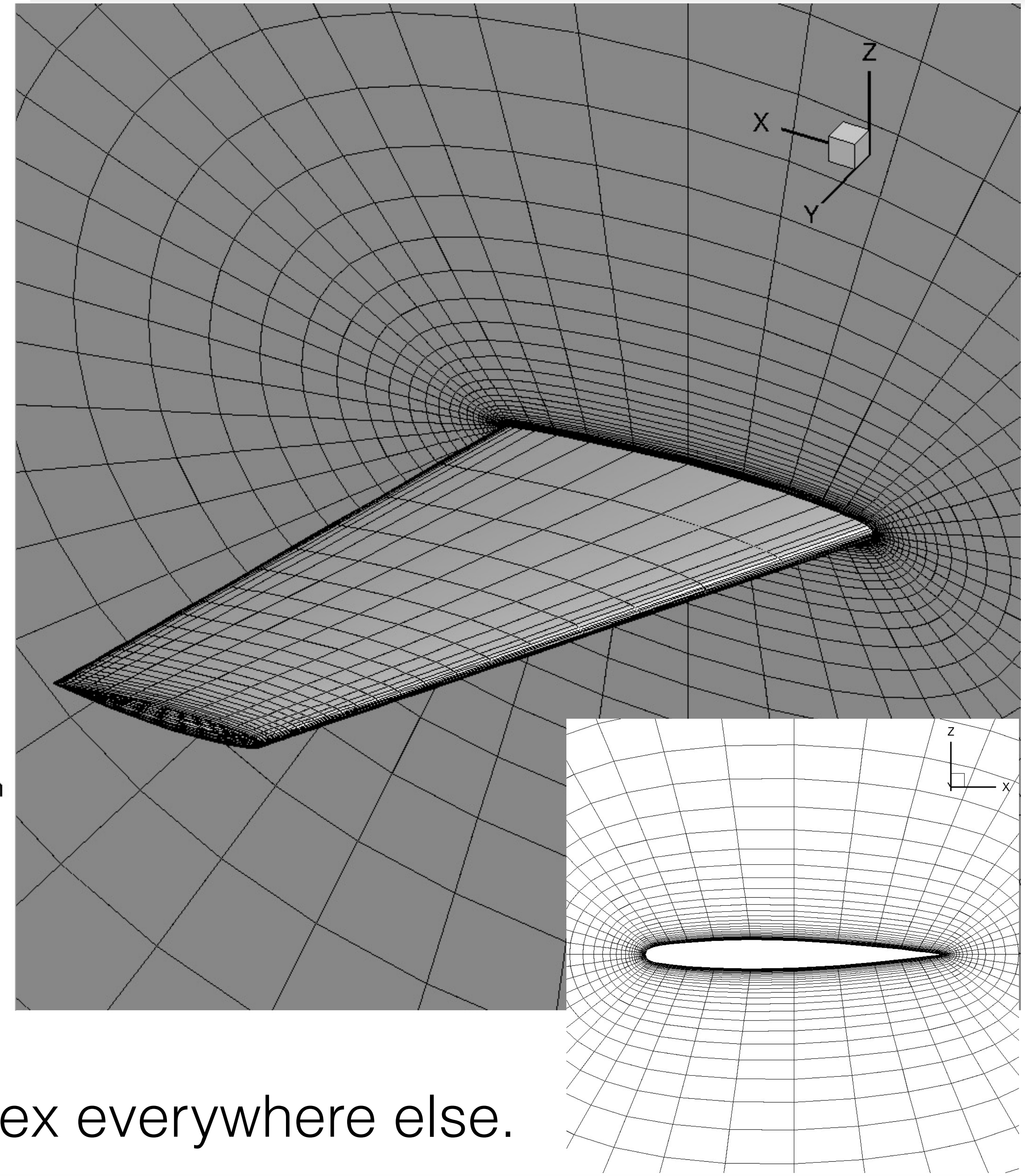




Thin prism layer over the wing surface; tetra everywhere else.

Prism-Hex





Prisms over the round tip to farfield; hex everywhere else.

Structured (Hex+prism)

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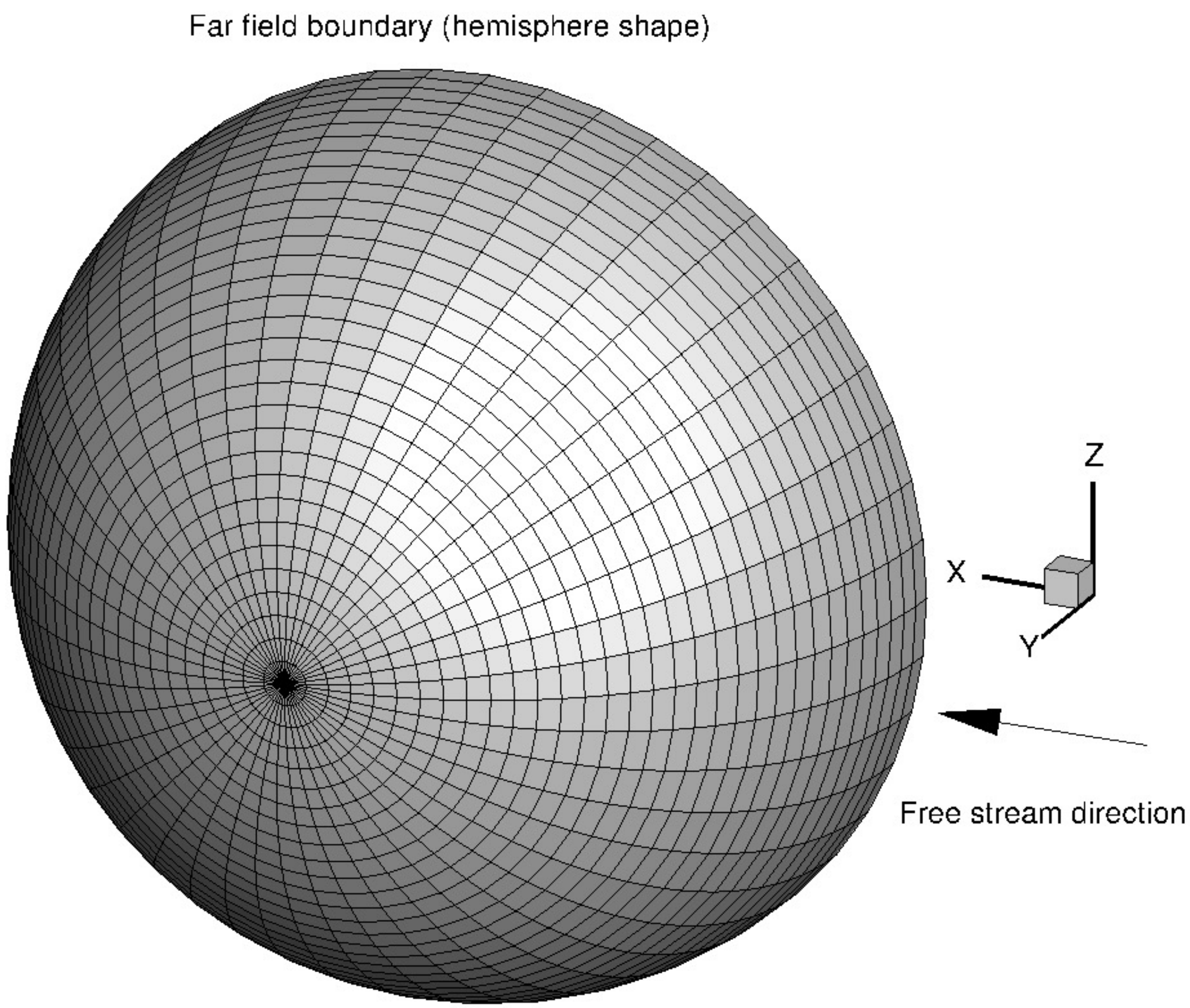

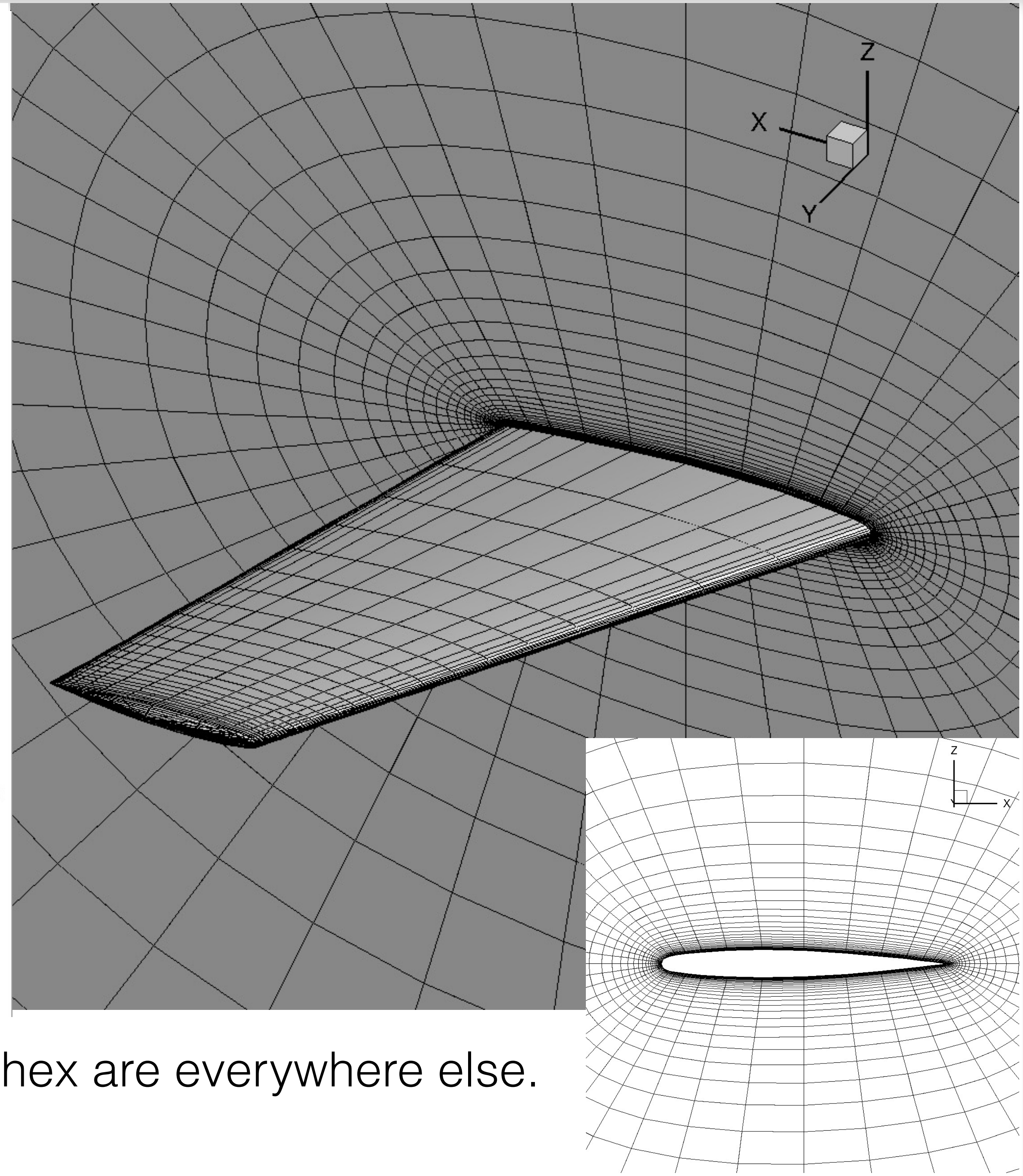

Prisms are around the center of the round tip; hex are everywhere else.
(Prisms extend to the farfield.)

Package

Download wing_v3p3_release_light.tar.gz at TMR website:

ONERA M6: NASA Langley TMR website

%tar -xvf wing_v3p3_release_light.tar.gz

- hcf_wing_v3p3.f90
- hcf_coarsening_v2p1.f90
- readme_release_light.txt
- sample_input , sample_input_coarsen
- sample_input_tets, sample_input_tets_coarsen

%source readme_release_light.txt

Sample structured grids and tetrahedral grids are generated.

readme_release_light.txt

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```
> Compile the codes
gfortran -o hcf_wing           hcf_wing_v3p3.f90
gfortran -o hc_coarsening  hcf_coarsening_v2p1.f90

> Generate a structured grid
hcf_hc < sample_input
```

```
#-------------------------------------------------------------------
# Endianness will be automatically detected, but if you wish,
# you can specify endianness at compilation: e.g., as follows:
#  gfortran -O2 -fconvert=big-endian -o hcf_wing  hcf_wing_v3p3.f90
#        ifort -O2 -convert big_endian  -o hcf_wing  hcf_wing_v3p3.f90
#-------------------------------------------------------------------
```

```
> Generate coarser grids
hc_coarsening < sample_input_coarsen

> Generate a tetrahedral grid
hcf_hc             < sample_input_tets

> Generate coarser grids
hcf_coarsening < sample_input_tets_coarsen
```

Input parameters

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“sample_input” in wing_v3p2_release_light.tar.gz

```
14.6e6                        !Target Reynolds number based on the root chord (=1 in the grid).
1                             !Target y-plus value
2                             !Element-type: 1=prsm, 2=tets, 3=prsm/tets, 4=prsm/hex, 5=Strct
T                             !T = unformatted .ugrid/.ufmt, F = formatted .ugrid/.p3d
0                             !airfoil_type: =0 discrete airfoil data, =1 NACA00XX
om6_wing_section_sharp.dat    !Datafile for the discrete airfoil data          ; not used if airfoil_type = 1
0                             !Last two digits of NACA00XX (15 for NACA0015); not used if airfoil_type = 0
0.5625159852668158            !Taper ratio = (tip chord)/(root chord)
29.9990                       !Swept angle of LE line in degrees (not too large, please: e.g., < 40).
100                           !Distance to outer boundary (=radius of the outer hemisphere)
24                            !# of Elements along the semi-wingspan
1.476017976219800             !b = semi-span: per unit root chord.
8                             !# of Elements along the rounded tip divided by 2.
88                            !# of Elements in the radial direction (from wing to farfield)
2                             !wing_side: =1 for left wing, =2 for right wing.
0.0                           !root_le_x: = x coordinate of the LE at the root.
T                             !T = Write a boundary grid (Tecplot)
F                             !T = Write a volume grid (Tecplot)
T                             !T = Write a 'k'-file (required by the coarsening program)
T                             !T = Write line files (e.g., for line-relaxation)
T                             !T = Write .ugrid file (any type of grid)
T                             !T = Write .p3d/.umft and .nmf files (igrid_type = 5 only)
```

Note: Items in red are required for regular coarsening.

Airfoil Data

Currently, the code accepts only a symmetric airfoil.

NACAXX (airfoil_type = 1):

Specify the last two digits as input parameter.

Discrete data (airfoil_type = 0):

Provide a file containing the points that define the half-thickness of a desired airfoil (the number of points, followed by a list of x-coordinates, and then a list of y-coordinates).
Specify the filename as input parameter. The code constructs cubic splines from the discrete data, and uses it to generate a grid.

Example of an OM6 wing section is provided:
See “om6_wing_section_sharp.dat” **AIAA J. Vol. 54, No. 9, September 2016.**

Example: ONERA M6 Wing

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Airfoil data: “om6_wing_section_sharp.dat”

Data taken from **AIAA J. Vol. 54, No. 9, September 2016.**

Input parameters: **All input given for unit root-chord length.**

Target Re = 14.6e6
Leading Edge Sweep = 29.9990 degrees
Taper ratio = 0.562515985268158
semi-span = 1.47601797621980

Output

.ugrid/p3d(.ufmt) : Grid file
.mapbc : BC file

.lines_fmt : List of nodes in lines within the BL region
.lines_fmt_all : List of all nodes in lines to the outer boundary.
.k : Structured index file (for coarsening)

Tecplot boundary/volume files.

Regular Coarsening

for HC/Wing grids

`hcf_coarsening_v2p1.f90`

Regular coarsening

HC/Wing grids can be regularly coarsened by using the coarsening program (included in each package):

hcf_coarsening_v2p1.f90

It will coarsen a target grid (generated by the HC/Wing gird generation code) by removing every other node. It continues to coarsen grids until it is not possible.

Required Input files

Four files must be available for a target fine grid:

xxx.1.ugrid
xxx.1.lines_fmt
xxx.1.lines_fmt_all
xxx.1.k

where xxx = ‘hc_tetra’, ‘wing_tetra’, etc.

Make sure these files are generated when you generate a target fine grid by the HC/Wing grid generation program.

Coarsening level

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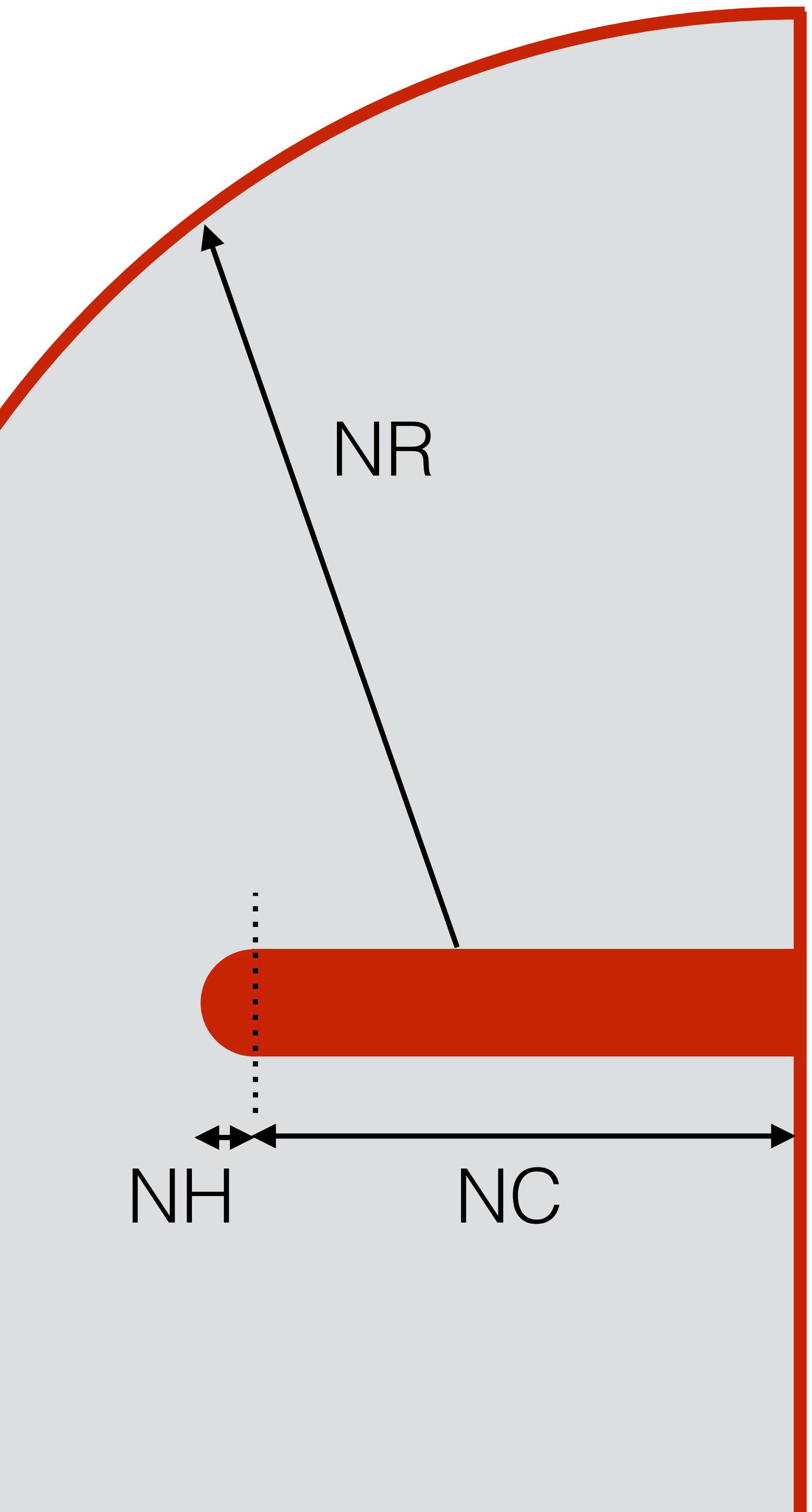
Coarsening level is determined by the input parameters used in the HC/Wing grid generation program.



Key input parameters.

NC !# of Elements along the cylinder
NH !# of Elements along the hemisphere (apex to shoulder)
NR !# of Elements in the radial direction

of Coarse Grids

# of coarse grids = min(m4, m1, m5)

— ***Structured:***

Full geometry

k4=NC+NH = 2^m4, k1=6*NH = 2^m1, k5= NR = 2^m5

Half geometry

k4=NC+NH = 2^m4, k1=3*NH = 2^m1, k5= NR = 2^m5

— ***Unstructured:***

k4=NC = 2^m4, k1=NH = 2^m1, k5=NR = 2^m5

HC/Wing grid generation code prints out the maximum possible coarsening level on screen as soon as it reads input parameters.

Input parameters

Sample input parameters for hcf_coarsening_v2p1.f90

Example for “hc_tetra”:

```
hc_tetra  !project name: = 'hc_prism', 'hc_tetra', ‘hc_mixed’, 'hc_mixed_ph', ‘hc_strct'
                           'wing_prism', 'wing_tetra', ‘wing_mixed’, 'wing_mixed_ph', ‘wing_strct'

T         !T=unformatted .ugrid (F=formatted)
F         !T=Tet2Prism on coarse grids, F=Keep tets
T         !T=Write a boundary grid (Tecplot)
F         !T=Write a volume grid (Tecplot)
```

It can generate all-prism coarse grids for a tetrahedral grid.

The code continues coarsening until it is not possible.

Output

.ugrid/p3d(.ufmt) : Grid files for all coarse grids.
.mapbc : BC file
.lines_fmt : List of nodes in lines within the BL region
.lines_fmt_all : List of all nodes in lines to the outer boundary.
.k : Structured index file (for coarsening)

.prolong_nc : Inter-grid interpolation information
.prolong_nc_seq: List of nested nodes
.midp : List of edge 'mid-point' coordinates.
can be used to create a P2 grid

Tecplet boundary/volume files.

Coarsening example (HC)

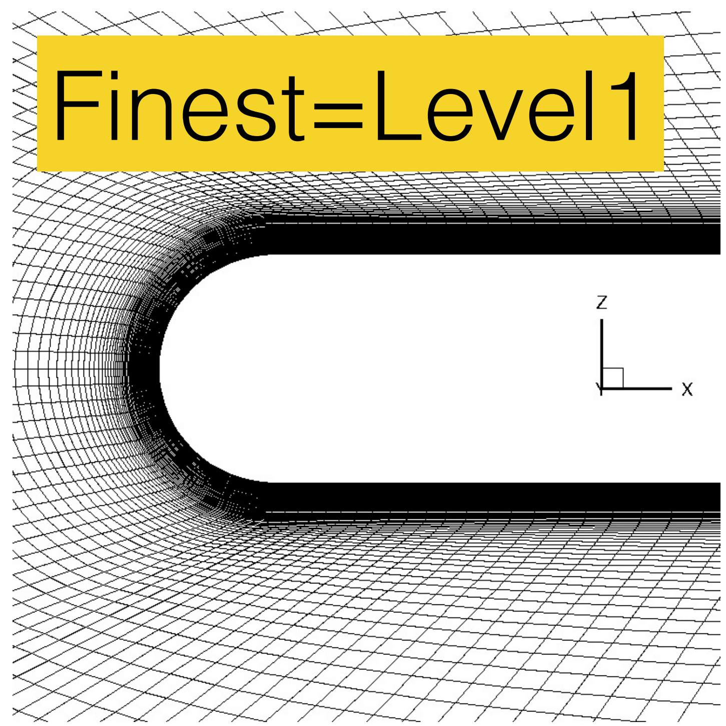
Structured grids:

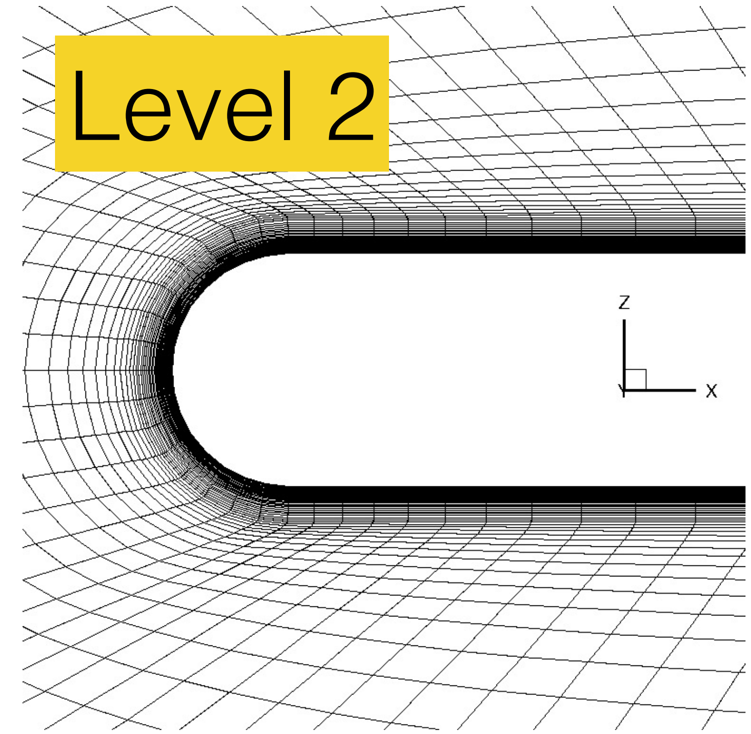
Half geometry

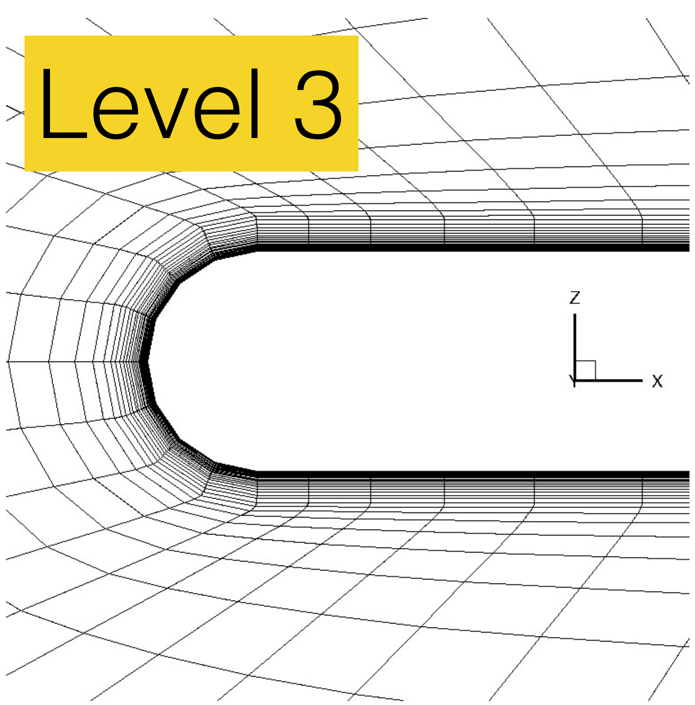
Finest grid generated by

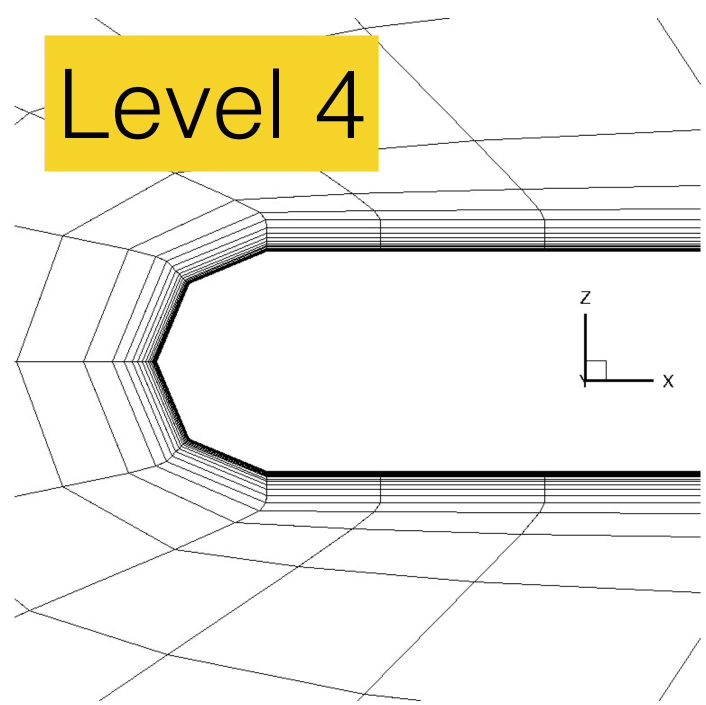
NC = 48
NH = 16
NR = 256

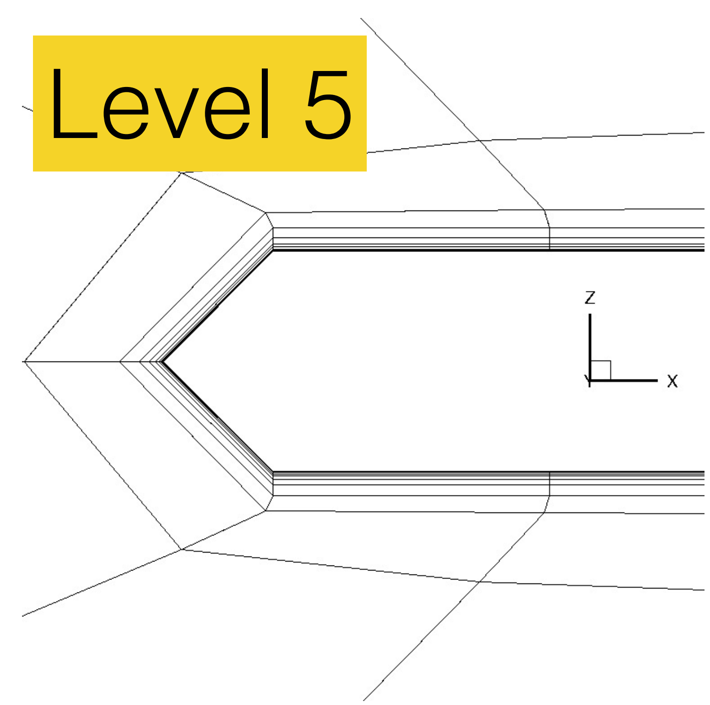
See “sample_input”











Coarsening example (Wing)

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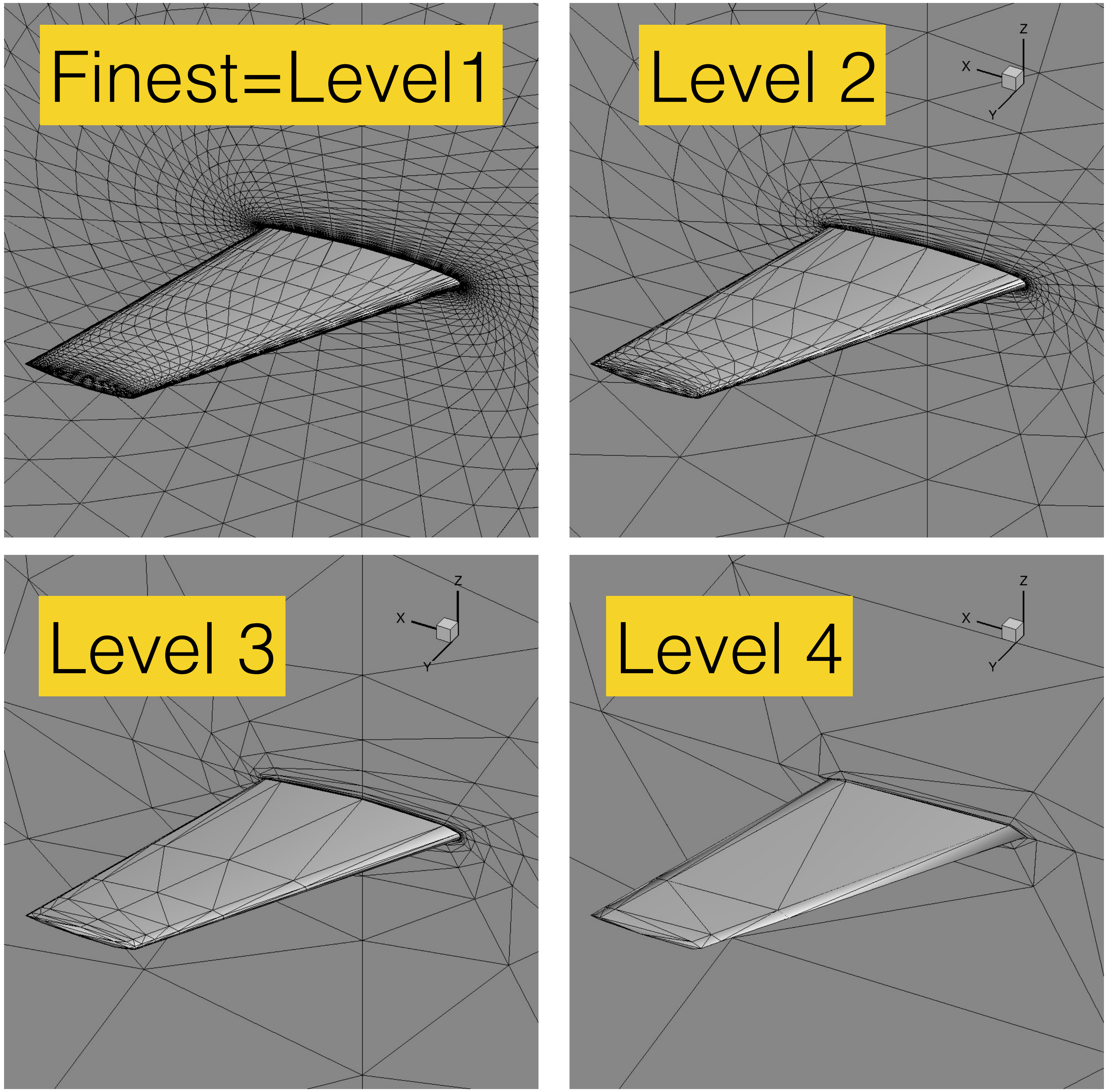
Tetra grids:

Finest grid generated by

NC = 24
NH = 8
NR = 88

See “sample_input_tets”



Inter-Grid Nodal Interpolation

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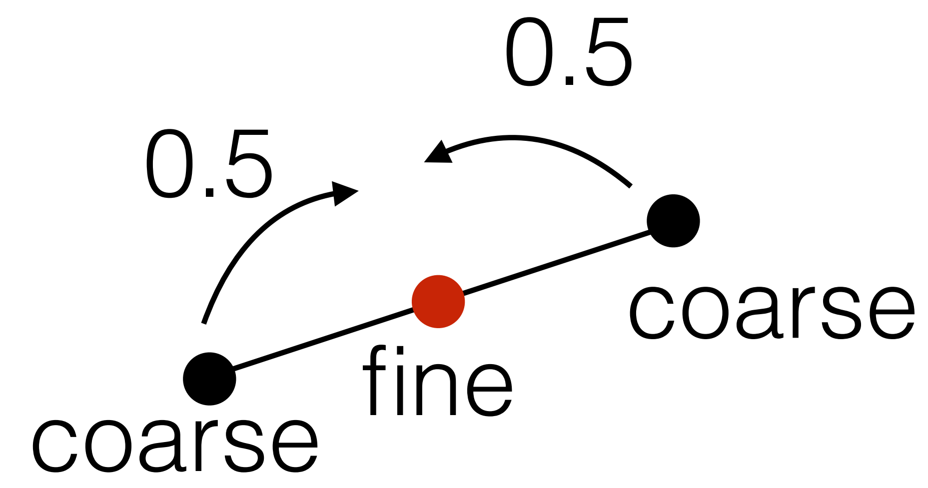
Inter-grid nodal interpolation information is given in two files:

.prolong_nc_seq (nested nodes) .prolong_nc (others)

Pure tetrahedral grids:

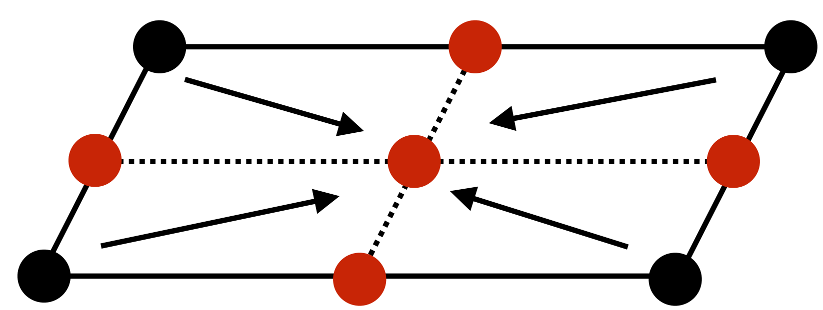


Injection at nested nodes.

Average over coarse-nghbr nodes.

Note: Find-grid node is not necessarily at the midpoint of the coarse-grid edge.

Other grids:



Injection at nested nodes.

Average over coarse-nghbr nodes.

Average over nearest coarse-grid nodes (if no nghbrs).

‘Midpoint’ data

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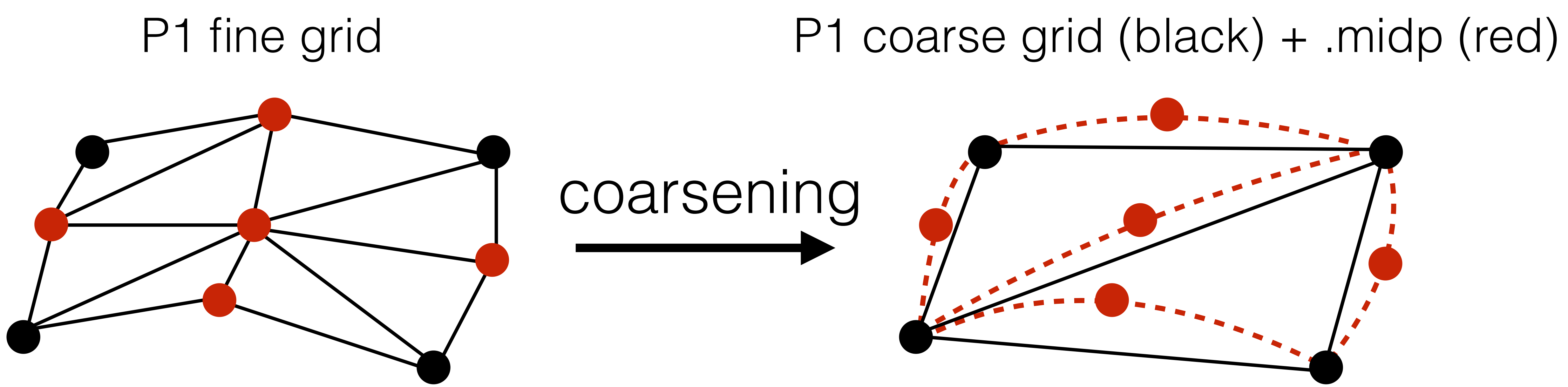
.midp file is generated for each coarser grid (tetra only).

This file contains a list of nodes removed from the finer grid, which correspond to nodes between coarse-grid edges (not exactly the edge-midpoint). These nodes are on the true geometry on the boundary. So, P2 tetrahedral mesh can be constructed for all coarser grids.



P2 grid indicated in red.